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ABSTRACT

This teaching guide was developed for use with Energy 80 program student booklets. Although the program was designed for junior high/middle school students in science/social studies classes, it is indicated that the materials are suitable for use at higher grades and, to a lesser extent, in upper elementary grades. The first 80 pages of the guide suggest ways of using the student booklet. Each of the 16 spreads in the student booklet deals with a separate topic, and the guide treats each spread separately. Included for each topic (spread) are objectives, reading level, background information, list of key vocabulary words, suggested activities and discussion topics, resources, and mini-quiz. The last three-quarters of the guide contains a selection of lesson plans, worksheets, and readings from the program, providing the basis for an interdisciplinary course in energy at the junior high school level. These materials are organized into eight units: energy fundamentals; energy from the sun; history and technology of fossil fuels; energy from nuclear fission; renewable energy resources; energy in the United States; economics and decision-making; and energy conservation. Rough outlines of two science and two social studies mini-units (using materials in the guide) are provided near the beginning of the guide. (Author/JN)

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ED224696

A Teacher's Guide to the Energy 80 student booklet

For the 1981-82 School Year

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Enterprise for Education, Inc. February, 1981

A Note to the Teacher

Here, in response to your request, is the first general distribution edition of ENERGY 80 materials. The generosity of businesses in your state made possible the printing and shipment of these materials to you. You might wish to know, however, that no corporate funding---or promise of funding---was obtained during the first years of the project. We are trying to make the program as comprehensive and unbiased as possible, and we look forward to hearing your reaction and learning how you used the materials.

WHAT YOU SHOULD HAVE RECEIVED

With this teacher's guide you should have received 30 copies of the booklet for students titled "ENERGY 80."

HOW THE TEACHER'S GUIDE IS ORGANIZED

The first 80 pages of this guide suggests ways of using the student booklet. Each of the 16 spreads (two facing pages) deals with a separate topic, and the guide treats each spread separately.

The last three-quarters of the book contains a selection of lesson plans, worksheets, and readings from the program. At appropriate points,the discussions of the spreads will refer you to materials in the rear of the book. But I hope you will take a few moments to browse through the appendix and get a feel for material's content and method.

WHAT YOU CAN DO

Of course , you could give students the booklet and ask them to read it. Results will be mixed, since students need time to digest the variety of ideas presented, and help in relating them to their own surroundings. You could deal with one spread a week over a semester. That would allow you to include some hands-on activities, which are extremely helpful.

You may choose to make use of a lesson or two within your existing course of study. Looking over the selection of lessons in this edition, I think you will find that particularly easy to do if you are teaching science or American History.

Some teachers will wish to consider teaching a mini-unit about energy using these materials. Rough outlines of four such units (two science, two social studies) are suggested near the beginning of the Guide.

WHEN YOU CAN EXPECT NEW MATERIALS

ENERGY 80 is intended to be improved annually. Each spring, funding permitting, we will send revised student and teacher materials to teachers who request them and who have helped to improve the materials. Spring shipment will give you a chance to examine the materials and to decide how best to use them in the coming year.

Besides incorporating revisions based on your comments and those of other teachers, the '82-'83 teacher's manual will include additional lesson plans. Many of these are in the units on renewable energy sources, economics and consumer decision making, and conservation. A number of these lessons are now circulating in draft form; I think you will find them interesting and useful.

WE NEED YOUR HELP

In two ways. First, this program is made possible by grants from a number of sponsors, a different set in each state. They would like to know what you think of the ENERGY 80 program, and specifically whether the materials are really being used and are helpful to you. Secondly, we need to know what changes and additions would be most helpful to you. To make this review and evaluation as easy as possible, a questionnaire on a prepaid business reply form labeled "A TEACHER'S REACTION TO ENERGY 80" is included at the rear of this book. Please examine the materials. Use them in the classroom this spring if you have the opportunity. And then, please, mail us your reply card no later than June 1, 1981. If you can take the time to write us a letter with more detailed comments, that would be very much appreciated.

ORDERS FOR THE NEXT EDITION OF ENERGY 80 DUE JUNE 1, 1981

New materials for the 1982-83 school year will again be available free of charge. The order form for these materials has deliberately been put on the same business reply form as the evaluation questionnaire. Without your help, we can neither improve the materials nor raise the funding. So no evaluation, no materials.

> No request for materials from a school previously provided with materials can be honored if a completed evaluation has not been returned.

IN-SERVICE TRAINING

In California, workshops are being offered wherever possible in coordination with district curriculum offices, by regional trainers. Newsletters will notify teachers of workshop dates and locations.

In Massachusetts, in-service training is being coordinated by Professors Robert Dillman and Robert Boutilier of Bridgewater State College. They and eight other faculty members in other parts of the state will be offering eighty 3-hour and six day-long workshops this spring and next fall. In addition, Drs. Dillman and Boutilier have agreed to man a hotline to provide aid when you need it. If you have a question about the ENERGY 80 materials or in-service training, call 800-342-3794 and leave a message for the "ENERGY 80 CENTER" along with your name, school, community and phone number (including area code) . Dr. Dillman or Dr. Boutilier will return your call within 48 hours. In the unlikely event they cannot help you, they will refer the question to our office and we will see what we can do. A spring and fall newsletter will also be sent to your school.

In Oklahoma, in-service training is being coordinated by the Oklahoma Council on Economic Education. In particular, we refer you to BUSED 5660 Workshop offered by the Center for Economic Education at Oklahoma State University. For more information, contact the Council's Executive Vice-President, Professor Clayton Millington at Business Building Room 112; Stillwater, Oklahoma 74074 (405-624-5204x).

In Texas, plans are still under discussion at the time we go to press; specifics will be announced in a newsletter in the Spring of 1981. Guiding the planning are Terry Brandt and Caroline Penn of the Harris County Department of Education and the members of the Editorial Advisory Board for Texas, some twenty-five district science and social studies curriculum directors.

As you've probably noted, preparations for in-service are in a more advanced stage in Massachusetts than other states. This is in part due to the early assistance of the Massachusetts Business Roundtable, which made it possible to get down to specifics at an earlier date. We expect that by the fall of 1981 each of the listed states will have different but equally comprehensive provisions for in-service.

John Lord
Editor
Energy 80

A Teacher's Guide
to the
Energy 80
student booklet

Enterprise for Education, Inc.

Both as a teaching guide and an annual publication, this publication falls outside the scope of the Library of Congress Cataloging in Publication Program. We suggest the following card entry:

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(An element of the Energy 80 program.)

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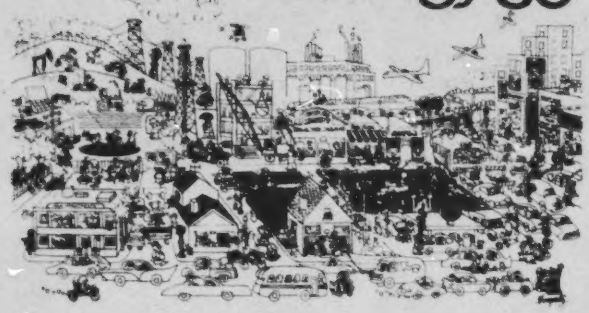
Energy 80



With this teacher's guide you should have received at least 30 copies of a student booklet. This guide suggests ways of using the booklet, and also introduces the Energy 80 program.

GRADE LEVEL = JUNIOR HIGH/MIDDLE SCHOOL

Teachers have also indicated the materials were suitable for use at higher grade levels, and even, to a lesser extent, the upper elementary grades.

SUBJECT AREA = SOCIAL STUDIES, SCIENCE

The most productive way of using the booklet depends upon your class and the time you wish to devote to the topic. Notice that each spread (two facing pages) in the booklet treats a separate topic. There are 16 spreads in all. The suggestions which follow are arranged spread by spread. At the end of this book is an appendix containing selected lessons and worksheets from the balance of the program.

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PROTECTING PARENTS' PRIVACY

The more closely energy education relates to the individual student's situation, the more effective it is. Collecting data about his or her own consumption of energy is one of the most fruitful things a student can do.

However, many families are extremely sensitive about sharing data on their family's energy purchases with other people. They have every right to their privacy in this matter. It can be very helpful if, before beginning any activity that requires the student to collect data on family energy consumption, you send a note home to the parents explaining the reason for the unit and stating that, while the student is required to do the homework, he or she is not required to share the information with you or the class. If you are concerned about your students not doing work that does not have to be turned in, consider asking parents to check that the data has been collected, providing them with a slip to sign that states they have done so.

Most of the discussions of the two-page readings in the student booklet contain the following items:

Vocabulary

You may wish to introduce some of these words prior to assigning the reading.

Resources

These brief references are especially intended to call attention to low-cost, no-cost materials.

Evaluation

A mini-quiz is provided for making a quick check of what students have learned from each spread. To make it easier for teachers who are not familiar with the subject matter to judge the correctness of answers, the quizzes mostly consist of simple recall questions. If you're knowledgeable on the topic, you will be able to think of higher level questions that would better evaluate the full range of student learning.

Also included are true and false questions. These are not intended for evaluation, but as a means of stimulating an oral class review at the close of periods.

ENERGY SOURCES (primarily for science classes)

The first week is devoted to establishing the idea of energy flow: we don't make or use up energy, we catch it on the fly.

Day	Purpose/ Activities in class	Assignment for next day
1	Focus student attention on topic Relate to student's own experience fill out worksheet, booklet p 1 note to parents if home energy data to be collected	read booklet pp 2&3
2	Review forms of energy Establish that energy flows from form to form, is not made discuss booklet pp 2&3 activity: convert energy from one form to another, such as lightbulb, appendix p 1-5	read booklet pp 4&5 complete matrix, appendix p 1-3
3	Reinforce flow concept with natural example, if sunny activity: water cycle demonstration, appendix p 2-3	read booklet pp 6&7
OR		
3	Another conversion activity, e.g., appendix p 1-7 or 1-11	
4	Reinforce flow concept with natural example activity: wind box, appendix p 2-9	read booklet pp 8&9
5	Natural example of stored energy: food Introduce fuel concept activity: calorimeter, appendix p 2-15	read booklet pp 10&11

ENERGY SOURCES (primarily for science classes)

Day	Purpose/ Activities in class	Assignment for next day
	In the second week, examine energy sources used in the economy.	
6	Establish usefulness of fuels to people see lesson app p 3-3	read booklet pp 12&13 worksheet app p 3-5
7	Coal Characteristics / early development reading, app p 3-18 activity in lesson app p 3-7 chart, booklet p 29 Establish present uses, chart booklet pp 22&23 Future use? discuss assigned reading	read booklet pp 14&15
8	Petroleum & Natural Gas Examine contribution, booklet pp 22 & 23 Discuss origin, occurence, extraction	read booklet pp 16&17
9	Nuclear Examine nuclear contribution on chart booklet pp 22&23 Examine mechanism, lesson on app p 4-11	read booklet pp 18&19
10	Renewables Examine need Examine operation of active & passive emphasizing absorption, transfer, storage	None.

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Evaluation

Students re-evaluate booklet p 1 responses

Test

EFFICIENCY (primarily for science classes)

Day	Purpose/ Activities in class	Assignment for next day
1	Review idea of energy conversion, do a conversion such as app pp 1-5, 1-7, or 1-11	read booklet pp 2 through 5
2	Prepare for efficiency investigation by measuring two forms of energy, see lesson app p 1-69	
3	Establish concept of efficiency through an investigation measuring efficiency, see lesson titled First-Law Efficiency, app. p 1-75	
4	Make practical application of efficiency concept, see lesson appendix p 1-83	worksheet in lesson
5	Use lesson titled System Efficiency, app p 1-89	read booklet pp 20 through 23

In the second week, shift focus to the role of efficiency in the economy and in possibilities for conservation.

Day	Purpose/ Activities in class	Assignment for next day
6	Discuss "waste energy" in economy use flow chart booklet pp 22&23 use worksheets on efficiency in guide.	Franklin Stove, app p 6-7 read booklet pp 28&29
7	Investigate opportunities for increasing efficiency at home and in school, emphasis on use of waste heat, control of heat	worksheet, app p 8-6
8	Continue home/school investigation. emphasis on habits routines that decrease efficiency	worksheet, 8-4 read booklet p 32
9	Efficiency in local industrial process: research in advance, get speaker if possible	read booklet pp 30&31
10	Evaluate role of efficiency in maintaining or improving quality of life while decreasing energy consumption	none

HISTORICAL PERSPECTIVE (primarily social studies classes)

As underlying questions to guide your study of U.S energy history, consider the following:
How has the abundance of America's resources influenced her people's use of energy? How has scarcity of labor affected our use of energy?
Is there a characteristic American attitude toward technical innovation and change, and if so, how was this affected our energy history?

In the first week, establish why we are studying this, some basic principles of energy use, and look at changes in energy use in the pre-fossil fuel period.

Day	Purpose/ Activities in class	Assignment for next day
1	Focus on history as a means of helping us understand the present today: talk of crisis, changes foreseen how is today unique? how like the past? Energy use in earliest colonial America examine in class & discuss Smith, app p 6-3 identify food, wood, gunpowder as energy sources	read booklet pp 2 through 5
2	Verify that students understand energy cannot be made, that there are limited number of sources. May wish to use booklet pp 2223 in discussion.	read Franklin, app p 6-7
3	What types of causes have lead to changes in the use of energy in the past? deduce wood fuel supply situation from Franklin what is Franklin's response to problem?	read Twain, app p 6-23
4	What changes are evident from Twain? the Coal Age, on to industrialization	read Wilder: Threshing, appendix pp 6-43 to 6-47
5	What has been the role of labor-saving machinery? why do attitudes to labor-saving (automation) differ scarcity of labor as a cause of American interest in labor-saving machinery	read booklet pp 12&13

HISTORICAL PERSPECTIVE (primarily social studies classes)

In the second week, we shift the focus to the various impacts of the fossil fuels.

Day	Purpose/ Activities in class	Assignment for next day
6	Establish time line for world coal use for use of coal in U.S.	Royal Proclamation, app p 3- read booklet pp 14&15
7	Establish time line for oil and gas use in U.S. Relate petroleum to rise of automobile How has automobile affected our society?	interview elderly person on energy used in home, work, transportation in their childhood
8	Relate rise of petroleum and gas to ease of use compared to coal	read booklet pp 20&21 worksheets, app pp 3-17 to 19
9	Review energy transitions in U.S. History use bar chart, booklet p 20&21	read booklet pp 22&23, 26&27
10	Energy and America's relation with rest of the world	readings in current local newspaper

CONSERVATION (primarily social studies)

The first week is devoted to establishing the reasons for our energy situation and the chief technical opportunity, increased efficiency.

Day	Purpose/ Activities in Class	Assignment for next day
1	Establish energy situation: precarious supply review oil import graph, booklet pp 14&15 review global sources, map booklet pp 26&27 review use of petroleum, chart booklet pp 22&23	read booklet pp 14 & 15, 26 & 27
2	Establish energy situation: in long run, fossil fuel depletion use lesson Depletion of Non-Renewable Resources, appendix p 3-37	read booklet pp 3 through 6 worksheet app p 8-2
3	Review basic physics of energy: energy flows through conversion after conversion, but can't be made; most of our mechanical energy now comes from heat; we can't get all the energy out of a conversion in the form we want.	worksheet app p 1-83
4	Learn to read utility meters see lesson in app pp 1-39	worksheets
5	Learn to understand utility bill see lesson app p 1-49	worksheets which you must make

CONSERVATION (primarily social studies)

Day	Purpose/ Activities in Class	Assignment for next day
	The second week is devoted to examining how energy can be conserved and what the effects of conservation might be.	
6	Improving use of heat in household	worksheet app p 8-7
7	Habits examine use of energy in school	worksheet app p 8-13
8	Efficient use of automobiles	read booklet p 32
9	Conservation in industry choose a local industry and examine its energy use arrange a telephone call to a plant official	read booklet pp 30&31
10	Examining whether we feel we must use more energy in order to have a good life.	none

MESSAGE; WORKPAGE

Reading Level: varies by state because of differing messages

Objectives

The student realizes that responsible people take the energy problem seriously.

The student assesses his or her present knowledge of certain aspects of the energy situation.

Background Information

Message

The message from the Governor (in California, the senior United States Senator) is provided as a means of conveying to students that knowledgeable people believe the energy situation is a serious problem.

Activities and Discussion Topics

1. Read the Governor's message. What particular aspects of the energy situation seem to be of most concern to him?

2. Might the situation in our state differ significantly from that in some other state? For what reasons?

3. Ask students to fill in the workpage on page one. If you must save the booklets for reuse next year, students can write the answers on a separate sheet of paper. You may choose to assign this as homework or to do it in class. The students themselves should be given a chance to correct their answers after they have used the materials, at the end of the unit. For your information only, here are the answers to the last set of questions:

Most energy last year = petroleum (5)
Most important in generating electricity = coal (1)
Greatest domestic production = natural gas (3)
Provided most U.S. energy in 1940 = coal (1)
Almost half comes from other countries = petroleum (5)
Provides most transportation energy = petroleum (5)
Comes from sunlight = 1, 2, 3, 5
Most important home heating fuel = depends on your location. Consult state or city energy office or utility if answer is not obvious to you.
Energy sources for electricity = phone the public affairs department of your local utility and request this information.

IN ALL THE UNIVERSE THERE IS ONLY...(pages 2 & 3)

Reading Level (by Fry count): 9th grade

Objectives

The student recognizes that there are different forms of energy.

The student recognizes that we cannot make or destroy energy.

The student is aware that energy can be converted from one form to another, and that almost every numan use of energy involves such a conversion.

With the use of supplementary lessons:

The student knows energy can be measured and can make some types of energy measurements, including temperature measurements.

The student is able to read utility meters and understand the form of utility bill used in his or her area.

The student recognizes that there are common patterns in household energy usage.

Background Information

Some students may raise religious objections to the headline. Emphasize that in this context we are only talking about the physical universe, things we can measure. In other frames of reference, other things would be important.

Most junior high school students will have learned about forms of energy in previous grades, so that aspect of this lesson is largely review. Often, however, they have not recognized that all uses of energy involve conversions.

Forms of Energy

The important point here is for students to realize that energy does take different forms and to be able to recognize some common ones. The conventional list of forms of energy used here is just a convenience. There are many other forms of energy, such as the elastic energy in a stretched rubber band, the surface energy of solids and liquids, the binding energy of the nucleus, and so forth. Though heat is commonly given as a separate form of energy, it is really energy of motion.

Incidentally, although it is common everyday usage to refer to the "heat stored in a body," this is meaningless from the physicist's point of view.

Heat, like work, is energy in transit. The temperature of a body can be raised by methods other than the transfer of heat; for example, by compressing a gas. For this reason, physicists prefer to lump everything together and refer to the "internal energy of a system."

Activities and Discussion Topics

Elicit the names of some forms of energy from students. Point out that some forms of energy are energy in transit, like heat and mechanical energy (work), while others are stored energy, like potential energy of the water at the top of a waterfall or the chemical energy in a battery.

On appendix page 1-3 is a worksheet which asks students to fill in various means of conversion. Students should not be expected to be able to fill all the cells of the matrix.

Then discuss the question raised in the text. Here are the answers:

Motorcyclist: chemical energy in gasoline to heat to motion; motion to electricity (due to the generator) to light and heat.

Woman in robe: hairdryer, electricity to heat and motion; toaster, electricity to heat and light, motion is stored as potential energy in spring, then converted to motion again; coffee pot, electricity to heat, heat to motion (of the coffee); radio, electricity to heat and motion (the sound).

Race Official: chemical energy in the cartridge to heat to motion (of the gas coming out of the barrel).

Cyclist: chemical energy of food to motion; in the generator, motion to electricity, electricity to light and heat in the headlight.

Woman sharpening knife: chemical energy (from her food) to motion to heat.

Brownie with magnifying glass: light to heat.

Boy Scout: chemical energy (from his food) to motion to heat.

Diogenes: chemical energy of lantern fuel to heat and light; in the television set, electrical energy to heat, light, and motion (the sound).

Man with flashlight: chemical energy in battery to electricity to light.

Further Concepts

This lesson can begin a set of lessons developing the following sequence of concepts:

Energy exists in different forms.
Energy is converted from one form to another. This is perhaps best
    taught through hands-on experiences, see samples in appendix pp
    1-5, 1-7, 1-11. These lead to an understanding of:
Energy is not created or destroyed.
Energy can be measured.
    Heat is the easiest form for students to measure. See appendix
        pp 1-17 through 1-31.

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Electricity. A lesson using rating plates on household appliances to introduce the units in which electricity is measured is included in the appendix on p 1-33. This should be followed by lessons on volts and amps, which are not provided because they are easily constructed.

Measurements of household energy consumption. See appendix pp 1-39 to 1-67.

Begin keeping personal consumption records for later analysis.

Measurements of energy in different forms can be equivalent. See lesson beginning on appendix p 1-69.

This leads to the subject of efficiency, treated in the next spread.

We believe these additional lessons are worth the effort because until students can compare amounts of energy, it is very difficult to say anything meaningful about energy use and production.

Mini-Quiz

1. Name one kind of stored energy. [any form except heat, work, light or electricity, for example chemical energy or potential energy]

2. Name any way of changing chemical energy to light. [combustion]

3. What kind of energy goes into an electric motor? What kind comes out? [electrical energy, electricity; energy of motion, motion, or kinetic energy]

4. What kind of energy does a car run on? [chemical energy]

5. What kind of energy do you run on? [chemical energy]

6. What kind of energy is present in natural gas? [chemical energy]

7. What kind of energy does a speeding bullet have? [energy of motion, kinetic energy]

8. Name a way of changing chemical energy to heat. [Burning or combustion is the usual answer; there are others which would be correct.]

9. In friction, what form of energy is converted to what? [motion to heat]

10. What is the name of a device for changing electricity to motion? [electric motor, or anything incorporating an electric motor]

True or False?

Energy is destroyed when you blow out a candle. [F]

As a candle burns, energy is destroyed. [F]

Someday, someone may succeed in building an engine that will move cars and not need any fuel or outside energy source. [F]

ENERGY...RULES OF THE GAME (pages 4 & 5)

Reading Level (by Fry count): 8th grade

Objectives

Students expect that in any practical energy conversion, part of the energy will be converted to heat.

Students describe efficiency as way of describing what percentage of the energy we put into a conversion will come out in the form we want.

Students realize that devices doing similiar jobs may have very different efficiencies.

Students recognize that there are theoretical limits on the efficiencies of various conversions.

Students appreciate the importance of looking at as much of an energy flow as possible, not just at one component.

Students recognize the economic importance of the conversion of heat to work.

Vocabulary

efficiency
system efficiency heat engine

Resources

The Project for an Energy-Enriched Curriculum (NSTA) has prepared a module for grades 11-12 titled There's Enough Energy, So What's the Problem, which is available free from DOE/TIC, P.O. Box 62; Oak Ridge, Tennessee 37830. Energy and Order, by Mark Dewitt and Paul Terry also treats thermodynamics in a teachable fashion (San Francisco: Friends of the Earth, 1976).

Background Information

System Efficiency

Notice that the efficiency of a system is found by multiplying together the efficiencies of all the components.

The numbers chosen are representative of commonly encountered appliances and utility systems. One could find gas heaters that were more efficient than 46%, and gas utilities with much higher losses.

Sometimes the efficiency of an electric water heater is given as 99%. (Theoretically, electricity can be converted to heat at an efficiency of 100%.) The 79% figure comes from considering the whole system within the house, from fuse box to heat at the tap, not just the conversion efficiency of the heating elements.

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Does the fact that the gas system shown is more efficient than the electrical system shown lead to the conclusion that a homeowner is better off heating water with gas than with electricity? NO. We need to look at the homeowner's particular system.

First, what source of energy was used to generate the electricity? For the sake of the comparision, in the example the electricity was generated by burning natural gas. Only about 15% of U.S. electricity is being produced from gas. In an area where electricity is generated in long-established hydroelectric plants, it may be more sensible to use the renewable electricity for water heating and save the gas for other uses such as very high temperature heating. Similiarly, nuclear fission can only be used for home water heating when it is distributed in the form of electricity. If it is thought desirable to save gas by substituting nuclear where possible, then it would make sense to heat home water with electricity rather than gas.

Secondly, how is the electricity used? In the example, the electricity was converted to heat as it is in an electric stove: by running it through a resistance element. Most electric water heaters work this way. It is not the most efficient way of heating water with electricity. It would be far better to take advantage of the fact that electricity can be easily converted to work, another high-quality energy form. An electric motor running a heat pump could deliver an amount of heat (taken from groundwater or the air) far greater than the heat equivalent of the electricity consumed. Substituting such an electric water heater for the electric heater in the example would produce a system which would have a higher system efficiency than the gas water heater system has. (There are also more efficient gas heaters.) A similar system preheats water using the heat exhausted by air conditioners, and again, the heat is made available by the work done by an electric motor. Both heat pump water heaters and air conditioner water heaters are practical systems presently in use.

Lastly, you use what you've got. If a mile of gas main would have to be laid just for you to use gas to heat water, your energy savings would never approach the energy needed to make and install the pipe.

How can a person decide questions like which is best in a particular situation, the gas water heater or the electric water heater? Though not infallible, cost is a pretty good guide. The method with the lowest lifetime cost is likely to be the one that uses the least energy. Deciding on the basis of cost also has the advantage of taking into account indirect energy consumption, for example to manufacture and deliver the heaters.

Heat Engines

In all heat engines, heat flows from a high temperature reservoir (commonly called the source) to a low temperature reservoir (the sink). Part of the heat flow is converted to work. In the early 1800s, a French engineer named Sadi Carnot perceived that no matter how this was done, there was no way of changing all of the heat energy to work, and the percentage that could be changed was determined by the difference in temperature of the source and sink. Later scientists found a mathematical expression for the theoretical efficiency:

$$\text{efficiency} = 1 - \frac{\text{temperature of sink in degrees Kelvin}}{\text{temperature of source in degrees Kelvin}}$$

Zero degrees Kelvin (absolute zero), which is about -273°C, is as cold as it gets. Celsius temperatures can be converted to Kelvin by adding 273.

Note that the theoretical efficiency can never be achieved in practice, because of friction and other inevitable losses. No gasoline engine has an actual efficiency anywhere near 60%.

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The nearer the thermal efficiency of any device gets to the theoretical limit, the harder it is to make further improvements, whether we are talking of power plants or locomotives.

Activities and Discussion Questions

Efficiency and Waste Heat

The reading gives the example of a fan getting warm. Ask students if they can think of other examples of energy uses in which unwanted heat is produced. In the classroom? (heat from lights?) In the car or bus on the way to school? (heat from engine) In almost any energy conversion, waste heat will be produced.

Can they think of anything we could use the waste heat for?

For further information on this topic, see the lesson First-Law Efficiency on appendix p 1-75. The succeeding lesson, Incandescent v. Fluorescent Efficiency, provides a practical application of the principle.

System Efficiency

Please refer to the lesson plan, Systems Efficiency, appendix p 1-89 for overhead transparency masters and other information on this topic.

Heat Engine

List some different heat engines. What produces the heat? Where does the heat go? Can you think of any devices that produce mechanical energy that are not heat engines.

Consider using the worksheet on appendix p 3-29.

Mini-Quiz

1. In all conversions of energy from one form to another, part of the energy is converted to what form of energy? [Heat]

2. A number which compares the amount of energy we get out of an energy conversion in the form we wanted, with the amount of energy we put in, is called what? [efficiency]

3. Which is more efficient, an incandescent light bulb or a fluorescent light? [fluorescent]

4. Two electric lights use the same amount of electricity, but light A gives more light than light B does. Which light is more efficient? (light A]

5. Two electric fans produce exactly the same air movement. Fan B uses less electricity than fan A. Which fan is more efficient? [fan B]

6. The people who design turbines, like jet engines, are making a great effort to find new materials for the turbine blades. They are trying to use materials like ceramics, because metals lose their strength at the temperatures at which the engineers would like the engines to operate. But the ceramics are brittle and keep breaking. Why are the engineers wasting so much time trying to get the engine to run at higher temperatures? [to increase the efficiency of the turbines]

7. What do we call a machine that changes heat to work? [a heat engine]

8. If we want to find the theoretical efficiency of a particular heat engine, what will we have to measure? [temperature]

9. Name two different kinds of heat engines. [steam engines, gas turbines, internal combustion engines, etc]

10. If we follow the loss of energy as it flows through a series of different machines, we are looking at what kind of efficiency? [system efficiency]

True or False?

Diesel locomotives are not as efficient as the last of the steam locomotives were. [F]

A steam turbine is a kind of heat engine. [T]

An automobile converts about 80% of the energy in the gasoline into forward motion. [F]

Photosynthesis is a very efficient process compared to an electrical powerplant. [F]

Anything with an efficiency of less than 50% is no good. [F]

OUR SUN...ENERGY SUPERSTAR (pages 6 & 7)

Reading Level (by Fry count): 7th grade

Objectives

Students recognize that all major energy flows on earth begin with sunlight, in particular the water cycle, wind energy, and the energy of living things.

Students recognize that materials are not used up in the wind, water, and photosynthesis-respiration cycles.

Students realize that an enormous quantity of energy reaches the earth in the form of sunlight.

Students recognize that sunlight is a diffuse energy source, in contrast to concentrated sources like fossil fuels.

Vocabulary

photosynthesis
wind cycle
water cycle

Resources

Consult "Resources" on page 23.

Background Information

The headline refers to the sun as an "energy superstar," which it is to earthlings. However, as stars go, the sun is a very ordinary, medium-sized star.

The earth is so small and so far from the sun that only about a billionth of the energy the sun radiates into space is intercepted by the earth's outer atmosphere. Of that intercepted energy, it is estimated that about:

30% is reflected away as visible and ultraviolet light (Earthshine, which we sometimes notice as illumination of the darkened portion of a new moon.)

47% is absorbed in the atmosphere and reemitted, mostly as infrared radiation

23% is associated with evaporation and precipitation (the water cycle)

0.215% is associated with winds, waves, and ocean currents

0.023% is captured by photosynthesis

As these figures show, by far the greatest part of the solar energy that reaches the earth's surface is used to evaporate water. (Some have said Earth should have been named Water.) This process provides most of the energy evident in weather. The energy of violent storms is mind-boggling; it has been estimated that an ordinary thunderstorm involves 20,000,000,000 Btu, while the energy released in a single day by a mature, moderately-sized hurricane is about 50 quadrillion Btu, about the same as the entire amount of energy used in the U.S. economy in 1970.

Note that horsepower and watts measure the rate at which energy is being supplied or converted. They do not measure an amount of energy. By saying how long the energy was being supplied at that rate, we could specify an amount of energy. Horsepower-hours and watt-hours do measure a quantity of energy.

Wind

Wind is a large-scale example of a convection current, like boiling water in a pot or the clouds of cold cream in hot coffee.

Different parts of the earth receive different amounts of light energy per square meter, because the sun is more directly overhead in the tropics than the polar regions. A time-proven demonstration of this uses a dozen sharp wood pencils held together with rubber bands. The pencils represent rays of light. Hold them perpendicular to a sheet of paper and jiggle them slightly, so that each pencil makes a mark. This represents the tropics. Now do the same for the polar regions, letting the pencils meet the paper at a pronounced slant. Which piece of paper has more marks per square inch? The one with the sun overhead.

The resulting unequal heating of the earth causes the convection currents we call winds. The air rises over warm areas and sinks over cold. Winds must move in a circle (a convection cell). Therefore the direction of the winds at ground level can differ from that at high altitudes.

This simple picture is changed by many factors, principally the earth's rotation. Most geography and earth science texts explain these complications.

Photosynthesis

Like the wind and water cycle, photosynthesis is part of a cycle. It has been estimated that every 300 years an amount of carbon equal to the entire stock tied up in living things passes through the cycle; it takes 2000 years for the stock of oxygen to be recycled. It is extremely likely that you have breathed some of the same molecules of air that Julius Caesar did. Photosynthesis is considered in more detail in the next spread.

Water Cycle

Note that when water evaporates, energy is stored in the vapor. When the vapor condenses, heat is released.

The water cycle is an example of a natural process by which the diffuse energy of sunlight is concentrated. Collecting the potential energy raindrop by raindrop would be impossible. However, thanks to rivulets, streams, and rivers, large quantities of water are assembled at points well above sea level. At such sites it is feasible to erect mills and hydroelectric plants to exploit the water's potential energy.

What Kinds of Energy on Earth Don't Come from the Sun?

Very few, namely:

Geothermal energy, which mostly comes from the decay of naturally-occurring radioactive elements in the earth.

Tidal energy, which comes from the earth's kinetic energy as it spins on its axis and moves in its orbit. As this energy is converted to heat over the eons, the day gets longer by 0.001 seconds per century.

Nuclear energy, which comes from human activities that convert mass to energy.

Activities and Discussion Topics

Enormous Amount and Diffuseness of Energy in the Sunlight Received
Let's do some back-of-the-envelope estimating on the chalkboard.

1. The United States has an area of about 3,631,407 square miles, which is about 9.5 trillion square meters. (1 square mile = 2,589,988 square meters) If one square meter is receiving light energy at a rate equivalent to one horsepower at noon, how many horsepower is the whole United States receiving? If one square meter is receiving light energy at a rate equivalent to 600 watts, how many watts is the whole United States receiving?

2. If a square meter received one horsepower, and assuming all the energy could be converted to work (100% conversion efficiency), how many horsepower would a solar-powered car be on a bright sunny day?. [ANS: If a car covers six square meters, six horsepower.]

> So, sunlight is a diffuse energy source compared to the concentrated ones we are accustomed to thinking of, but taken altogether the quantity available is enormous (and, in the long term, it is ultra-reliable).

Wind: an example of the power of sunlight

3. What use did people make of wind in pre-fossil fuel days. (Sailing)
4. Have you ever seen a windmill? What work did it do?

Please see the lesson titled The Wind Cycle on appendix p 2-3.

Water

Have students make a diagram of the flow of water in the water cycle. Then try to add energy to it.

Please see the lesson titled The Water Cycle on appendix p 2-7.

Mini-Quiz

1. About how many watts of sunlight fall on a square yard at noon? [500 watts]

2. What is the name of the process by which plants store light energy as food? [photosynthesis]

3. At the equator, would you expect air to be rising or falling? [rising]

4. It is too bright in my room. I pull dark shades over the window. What form of energy is the light converted to? [heat energy]

5. What form of energy is present in wind? [energy of motion, kinetic energy]

6. Before 1800, what source provided the energy for travel between Europe and America? [wind]

7. When a wet towel dries, what has become of the water? [It has turned to water vapor.]

8. What is the name of the process by which water vapor becomes liquid water again? [condensation]

9. A farmer is getting electrical energy from his wind-powered generator. What did this energy lookl like when it first reached Earth? [sunlight]

10. The energy animals use to move comes from their food. Before it was food, what kind of energy was it? [light]

True or False?

The sun will not go out for billions of years. [T]

Some objects do not absorb any light at all. [F]

In a few million more years, all the rain will have fallen into the oceans and there will be no more rain. [F]

[OUR SUN] ...PROVIDES FOOD ENERGY (pages 8 & 9)

Reading Level (by Fry count): 8th grade

Objectives

Students recognize that the energy required for all life activities comes from the sun.

Students recognize that all materials in the photosynthesis-respiration cycle are recycled.

Students are aware of additional energy inputs in the U.S. food system.

Resources

An excellent compendium of lessons on this topic is "Energy, Food, and You," available in either an elementary or secondary edition (specify) for a $5 check payable to Environmental Education/E.S.D. 189 from Shoreline School District Admin. Bldg.; NE 158th and 20th Avenue NE; Seattle, WA 98155; attn Tony Angell.

Background Information

How Plants Trap Energy

Note that the oxygen given off comes from the water molecule, not from the carbon dioxide molecule. Scientists can demonstrate this using radioactive tracer isotopes of oxygen.

The text emphasizes photosynthesis in leaves. However, of the estimated 200 billion tons of carbon annually incorporated in living things as a result of photosynthesis, only 20 is fixed on land, and 180 in the oceans, mostly by plants that do not have leaves, the one-celled algae.

A minor exception makes it incorrect to state that all photosynthesis takes place in green plants. There are a few odd bacteria which carry on photosynthesis.

The formula shown is a summing up of the results of photosynthesis, not a step-by-step description of that complex process. Such descriptions are available in high school texts or an excellent series of articles in *Scientific American*.

Passing Food Energy Along

Here the word chain is used, which can perhaps describe one meal. However, because animals may eat a variety of plants and animals, the phrase "food network" is more accurate.

The loss of 90% of the energy at each step in the chain is typical, but the percentage varies.

Actually, people do not need proteins but the amino acids from which the proteins are made. There are eight amino acids people must obtain from their food; all the others can be synthesized by the human body. For example, wheat by itself is poor in the amino acid lysine, but wheat can be can be eaten with other plant foods high in lysine, like beans. Thus it is possible for people to get all the proteins they need without resort to meat. But it isn't easy.

Cashing In Your Chips

Biologists give the name respiration to the process of obtaining energy from food. (Breathing they call external respiration.)

Note that respiration is just as essential to plants as it is to animals.

Takes More Than Sunlight to Set the Table

The amount of energy needed to produce a calorie of food energy varies greatly. In general, the higher up the food chain you go, the more energy required per calorie of food.

Activities and Discussion Topics

Review the Photosynthesis-Respiration Process

On the chalkboard, review the inputs and outputs.

Balance the equations by counting the number of atoms of each element in what we start with and what we end up with. Verify that no materials are lost.

Students can make a crude measurement of the energy content of food. On appendix p 2-15 is a lesson plan, Measuring Food Energy, including an activity in which students make and use a crude calorimeter.

Food Chains

A worksheet that helps students investigate their own food chain is provided on appendix p 2-19.

Energy Use in the Food System

A worksheet which can serve as a brief introduction to one aspect of energy use in the food system, transportation, is provided on appendix p 2-20.

Mini-Quiz

1. Name the three chemical elements that are recycled in the photosynthesis-respiration cycle. [carbon, oxygen, hydrogen]

2. Sugars and starches are made of these elements. That is why sugars and starches are called what? [carbohydrates]

3. What form of energy goes into the energy conversion we call photosynthesis? [light energy]

4. What is the name of the gas we give off as a result of our use of energy? [carbon dioxide].

5. What is the name of the gas plants give off as a result of photosynthesis? [oxygen]

6. As energy is passed along a food chain, about how much is lost at every step? [90%]

7. What is the name of the gas plants take for photosynthesis? [carbon dioxide]

8. What is the name of the unit used to measure food energy? [Calorie or kilocalorie]

9. What are the biggest sources of the energy used in the U.S. food system? [petroleum and natural gas]

10. When you eat a 1000 Calorie meal, about how may Calories of energy (other than food energy) were needed to put that meal on your plate? [100,000 Calories]

True or False?

Each year carbon is used up in photosynthesis and so eventually the world will run out of carbon. [F]

If there were no plants, only the meat-eating animals could survive. [F]

The energy you use to ride a bike came from a star. [T]

There is no limit to the amount of food energy you can obtain from an acre, provided you can put on as much fertilizer as you want. [F]

People are at the bottom of their food chain. [F]

FOSSIL FUELS... SUPER-LONG-STORED-UP FOOD ENERGY (pages 10 & 11)

Reading Level (by Fry count): 7th grade

Objectives

Students recognize that the energy of fossil fuels came from sunlight.

Students recognize that the fossil fuels were formed over eons through geological processes.

Students recognize that coal consists principally of carbon, and that there are different types of coal.

Vocabulary

peat
lignite
bituminous coal
anthracite
sediments
sedimentary rock
crude oil

Resources

Nowadays, most students have never seen coal or oil. Perhaps you can borrow some from the earth science teacher; suppliers like Ward's sell prepackaged kits of energy resource specimens. The National Coal Association (Coal Building, Washington DC 20036) provides a free pamphlet "Buried Sunshine" that has blister-packed to it some thumbnail-sized specimens of peat, lignite, bituminous coal and anthracite. These are better than nothing.

Background Information

Lately, the possibility that some natural gas is a remnant of the primordial methane present at the earth's formation (and is not biological in origin) has been discussed in the press. Most geologists appear to be skeptical.

Some school science collections include coal specimens which display the imprint of fern leaves. If you can borrow one of these, it makes a most convincing demonstration of the origin of coal.

Activities and Discussion Topics

1. How do you explain the fact that coal occurs in seams, or layers?

2. From your knowledge about how oil is formed, what kinds of clues would you look for if you were searching for oil? What kinds of rocks would you look for? Could looking for fossils help you find oil? What kind of fossils would you look for?

3. Are the fossil fuels formed quickly or slowly? Do you think any are being formed today? Which do you guess is faster, the rate of formation or the rate at which we are extracting them?

Mini-Quiz

1. Coal is mostly made of what chemical element? [carbon]

2. The energy we get from coal originally came from what kind of energy? [light, sunlight]

3. What is the name given to materials like sand and clay when they are deposited at the bottom of lakes and oceans? [sediments]

4. What do we call plant remains when they are in the first stage of changing to coal? [peat]

5. What is the name of the kind of rocks oil is found in? [sedimentary]

6. What kept the plants that turned into coal from rotting after they died? [Being covered with water.]

7. Why is most anthracite found in mountainous areas? [because the anthracite is formed by the heat and pressure that is part of mountain building]

8. How long ago did most of the plants that became coal grow? [300 million years ago]

9. What size are the holes underground in which oil and gas is found? [tiny]

10. Where did the plants and animals that became petroleum live? [in the ocean]

True or False?

As time passes, due to heat and pressure the layer of plant materials that will become coal grows thicker and thicker. [F]

Crude oil is a mixture of different substances. [T]

The layer of plant remains that was changed to coal might have been 20 times thicker than the resulting coal seam. [T]

We are absolutely certain how oil is formed. [F]

COAL: THE ONCE AND FUTURE KING? (pages 12 & 13)

Reading Level (by Fry count): 8th grade

Objectives

Students are aware that use of coal did not begin until the late Middle Ages.

Students recognize that exploitation of coal provided the energy for the development of industrialized societies.

Students identify coal as the dominant fuel in the U.S. from approximately 1880 to 1950.

Students are aware of some of the difficulties of extracting, transporting, and burning coal, and of controlling pollution, in comparision to other fossil fuels.

Students are aware of some air pollution control technologies.

Students know reserves of coal are greater than those of other fossil fuels, both domestically and worldwide.

Students know coal is the principal source of our electricity.

Vocabulary

[Industrial Revolution*]
*Words or phrases not in the reading which you may wish to introduce in discussion.

Resources

The Project for an Energy-Enriched Curriculum (NSTA) has prepared a number of units exploring the outlook for coal, including "Western Coal, Boom or Bust" (grade 11), "Coal: Promise and Problems," (grades 6-9); "Making Decisions About Synfuels" (grade 11-12); "Fossil Fuels and the Greenhouse Effect" (grades 9-12). These are available free on request from the Dept of Energy Technical Information Center; PO Box 62; Oak Ridge, TN 37830. An adequate free-loan film, "Coal, the Other Energy," (15 minutes) gives a history and a survey of the present challenges, using a senior high vocabulary. Some other free resources have been listed by topic in the "Background" section.

Background Information

Edward I and England's Transition to Coal

On appendix p 3-9 is a reproducible copy of Edward's proclamation. Accompanying it is a suggested lesson in which students compare the burning of coal and wood using the most primitive form of open fire.

The Industrial Revolution

Today we are accustomed to technological revolutions taking only a few decades, like the transistor, computer, and jet airplane. But that was not the pace of change in the Industrial Revolution. Neither the steam engine nor the perfection of iron smelting with coke were rapid changes. Almost a hundred years passed from Darby's discovery of how to employ coal to make marketable iron until the use of coal to make iron was universal. The first practical steam engine was made by Savery in 1698, improved by Newcomen and by 1725 in widespread use pumping water from mines. It was not until the 1780's that Watt's improved engine began to be widely used for purposes other than pumping. Students may wish to discuss why innovation procedes more rapidly in some times and places than in others. (Perhaps consider: communications systems, availability of capital, attitude toward innovation, etc.)

Notice that in Britain coal and the steam engine contributed to each other's spread, somewhat as coal and the locomotive did in the United States. In its initial century, the steam engine was mostly used to pump, not to rotate a shaft. The pumping was needed to drain the coal mines. Without the steam engine, production of coal would have fallen drastically. Without coal, no supply of fuel adequate to the steam engine's demand would have been available.

A set of three films on the Industrial Revolution, which emphasize the role of English principles of liberty and the individual entrepreneur, is available on free-loan from Modern Talking Picture Service. The presentation is by scholars and the films do show the actual historical sites. If you intend doing a social studies unit on the Industrial Revolution, these might be worthwhile.

The Transition to Coal in the United States

One of the distinctive features of the energy history of the United States is that wood was the chief fuel for almost a hundred years longer than it was in other northern hemisphere industrial nations. Students can usually figure out why this was so. It may be important to point out that in some nations in the world wood and other plant matter is still the primary source of inanimate energy. In fact, Brazil is presently using charcoal for industrial purposes like steel-making (for which it is excellent).

In the eastern United States some of the old ironworks have been preserved, like the Saugus Ironworks in Massachusetts and Hopewell Village in Pennsylvania. This can be a meaningful field trip which demonstrates how, before the use of coal, such industries were dependent on surrounding forests.

Transition from Coal to Oil and Gas

See appendix p 3-15 for a lesson comparing the convenience of coal and gas in domestic use.

See appendix p 3-21 for a lesson on the development of the internal combustion engine, another factor which contributed to the replacement of coal by petroleum and natural gas.

Estimates of U.S Coal Resources

The United States is believed to have larger coal reserves than any other country, and they are relatively easily mineable.

In order to compare reserves of various domestic mineral energy resources, estimates of the physical quantities of reserves can be converted to the amount of heat that could be obtained from them. Here is how the total "heat reserve" breaks down:

coal	81.7%
petroleum	2.8%
natural gas	3.5%
natural gas liquids	0.6%
bitumins and shale oil	7.2%
uranium oxide*	4.2%

*Assuming a price no greater than $30 a ton and use in a light-water reactor.

Mining Coal

Underground coal mining is one of the most dangerous of all major occupations. In 1978, underground miners suffered 47.84 disabling injuries per million tons mined; surface miners, only 5.29. (The difference is not just in the amount of coal produced per person. Underground miners suffered 50.47 disabling injuries per million man-hours worked; surface miners, 16.55.) Increasingly stringent regulations have contributed to lowering the fatality rate from 1.95 fatalities per million man-hours in 1926-30, to approximately one fatality per Mm-h throughout the 1960s, to .28 fatalities per Mm-h in 1978.

Transporting Coal

In 1976, 64% of the coal was moved from the mine to the point of use by rail, 13% by motor vehicles, 12% was transported as electricity from generators located at the mine-mouth, and 10% by barge. (One percent was "other.")

Increased use of coal naturally means an increased need for transportation. "Unit trains," which carry only coal are one efficient means of moving coal, but the towns though which the railroads pass are fearful of the effects of what might become continual rail traffic. In some areas, the poor condition of the roads is blamed on their use by heavy coal trucks.

To transport coal by pipeline, it is ground very fine and mixed with water (or sometimes, oil) to form a slurry. One such pipeline has operated successfully. Much of the western coal is found in arid regions, which poses a problem for this technique.

Making synthetic liquid and gaseous fuels from coal is another solution to the transportation problem, and it is also a means of reducing the pollution created at the point where the fuel is burned. Making a fuel gas from coal is a two-century-old industry. Most of the utility gas was once synthetic, but it had half (or less) the heat energy per cubic foot of natural gas. However, gas with a heating value comparable to natural gas can be made.

New Ways of Burning Coal

In fluidized bed combustion, a constant stream of air is blown through a bed of finely-divided particles of burning coal.

Activities and Discussion Topics

1. The ancient Greeks and Romans made little use of coal. It was only towards the close of the middle ages that use of coal began to develop. Why might people prefer wood or charcoal to coal?

Try burning some, see appendix p 3-7. Besides a dislike of the smell, people were not aware that coal required a greater draft than wood and would not burn well in tried-and-true stove and furnace designs that worked well with wood.

2. What might have caused people to overcome their reluctance to burn coal? (Some scholars believe that England's transition to coal began in an energy crisis at the close of the Middle Ages. They believe deforestation had created a fuel wood shortage, and that this was an impetus to the use of coal.

3. When did use of coal in the U.S. get started?

4. Have you ever seen any coal?

5. How is transporting coal different from transporting oil or gas?

6. The student booklet mentions smoke in London. London became famous for its pea soup fogs. Today, those fogs are gone. Why? What happened in Pittsburgh?

Mini-Quiz

1. What was the name of the first practical machine able to change the energy in coal into mechanical energy, or work? [the steam engine]

2. In the 1700's, the English perfected a way of using coal to produce what metal? [iron]

3. What is the chief problem in burning coal? [pollution]

4. There are basically two types of coal mining. Which type is commonest in the western United States? [surface mining]

5. Which type is most dangerous? [underground mining]

6. Why type recovers more of the coal in the seam? [surface mining]

7. Name one pollutant found in coal. [sulfur]

8. Coal was first used as a substitute for what other fuel? [charcoal, give half credit for wood]

9. What is most of the coal burned in the U.S. today used for? [to generate electricity]

10. In what decade did coal overtake wood as America's chief energy source? [the 1880s]

True or False

At the time of the American Revolution coal was the major source of energy in America. (F)

Coal mined in the eastern United States usually contains more sulfur than coal mined in the western United States. (T)

We have much more coal than oil. (T)

Surface mining is more dangerous than underground mining. [F]

OIL AND GAS PRODUCTION & CONSUMPTION USA 1859-1980 (pp 14 & 15)

Reading Level (by Fry count): 8th grade

Objectives

Students recognize that oil and gas are depletable natural resources.

Students are aware that petroleum did not become a fuel until the 1860's.

Students are aware that our oil imports have increased greatly in the past decade.

Students recognize that the quantity of oil which can be produced is dependent on how much the oil is worth to us.

Background Information

What Was the Significance of Drake's Well?

Many notions about Drake's well are not correct.

Petroleum was bought and sold in America in the 1700's, long before Drake. It was obtained from seeps and by skimming pools and creeks, and often called Seneca oil. Because of the difficulty of obtaining it, only small quantities were traded, but by the 1850's, there was an oil refinery in Ontario, Canada, producing lamp oil from crude oil obtained from seeps and springs.

Drake and his co-workers did not invent the well-drilling technique. Most of the credit for that is due to David and Joseph Ruffner, who drilled a well for salt water in West Virginia in 1806.

Drake was not the first to strike oil. In 1814, a brine well being drilled at Rennix Springs, Kentucky, struck oil at 475 feet. The crude flowed out into a nearby river, where it ignited in a blaze that stretched for fifty miles downriver.

Drake's well was not the first well intentionally drilled for petroleum. A unsuccessful well had been deliberately bored for oil ten years earlier in France.

Why did Drake's well begin the oil industry (as it did)? Some of the causes might have been:

Drake happened to drill in one of the largest shallow fields yet found. Not only that, but the oil was "sweet," a type that could be easily converted to lamp oil by the primitive refining methods of the day.

By Drake's time, a demand for oil had been established through the work of the coal oil refiners. People had suitable lamps. Moreover, the spread of literacy in a TV-less age increased the demand for illumination strong enough for reading after sunset.

The site of Drake's well was relatively convenient to the transportation system and markets of the day.

The Internal Combustion Engine

Like other motor car manufacturers, Ford at first made expensive cars, and was urged by his board of directors to make even more costly ones. The Model B cost $2000 in 1904. Instead, in 1908 Ford brought out the Model T at a price of $850. By 1914 it was selling for $490. In its 18 years of manufacture, 15,000,000 cars were sold in a country poorly served by all-weather roads. Ford's car not only lead to the remaking of the road system; it remade American society.

New Molecules

The first success the chemists had was with "cracking," breaking down the large molecules of heavy oils to make lighter fractions like gasoline that were more in demand.

This experience lead on to synthesizing molecules never seen before, such as:

material	date of first commercial availability
polystyrene	1930s
Neoprene	1936
butyl rubber	1937
Nylon	1939
Mylar/Dacron	1950s

Gas Pipelines

The building of long-distance transmission pipelines did not begin until 1926, when a 170-mile, 22-inch line was built in Louisiana. In 1931, building of gas pipelines consumed 75 per cent of the total steel pipe tonnage produced, and 7000 miles were laid. By 1948 there were 346,000 miles of gas pipeline network.

Discovery Rate

Nineteen-eighty was a boom year for exploratory drilling, thanks to the increase in oil and natural gas prices. Note that the graph of discovery rate does not include the discovery of the giant field at Prudhoe Bay, Alaska, which would create a big bump in 1973.

Activities and Discussion Topics

1. Why do people need artificial light? What are some ways of getting it? What ways would Americans have had a hundred and fifty years ago?

2. Brine is salt water, which is found in the earth at some places. Why would people two hundred years ago have valued brine? What would they do with salt? What alternatives were there to salting down meat and fish?

3. What do we mostly use petroleum for today? When did people first begin using it for that purpose? List as many uses of petroleum as possible.

4. Examine the import-export graph. What has happened since the Second World War?

5. Consider using the lesson on depletion of finite resources on appendix p 3-37.

6. Consider using the lesson on coal vs gas as a domestic fuel on appendix p 3-15.

Mini-Quiz

1. When oil was first produced by drilling wells, what was its most important use? [as kerosene for lamps]

2. What historical development changed gasoline from a useless by-product to a highly sought after product? [the invention of the internal combus-tion engine, the spread of the automobile]

3. Why did it take so much longer for natural gas to become an important fuel than it took oil? [Gas had to wait for the development of a pipeline system that would reach major markets.]

4. What is the name of the factory that converts crude oil to gasoline and other petroleum products? [refinery]

5. In what decade did we begin to consume more oil than we produced ourselves? [the 1940s]

6. In what decade did domestic production of petroleum decline for a number of years? [the 1970s]

7. What country was the largest exporter of oil in the early years of petroleum production? [the United States]

8. Recently, the amount of oil we import each year began to decline. In what year did we import the most oil? [1977]

9. What do we call the special ways of getting more oil out of old wells that have stopped producing? [secondary recovery, give full credit for enhanced recovery or tertiary recovery]

10. Besides being burned as a fuel, petroleum is used to make lubricants. Petroleum is also made into a material from which things can be made. What are those materials called? [plastics]

True or False?

Most oil estimated to be still in the ground in the U.S. is off-shore. [F]

By 1900, long-distance natural gas transmission pipelines reached most parts of the United States. [F]

The more oil is worth, the more barrels of it we can get out of the ground. [T]

The oil industry began in Pennsylvania. [T]

There is no more oil to be discovered in the United States. [F]

There have been times in the past when Americans believed they were running out of an energy resource. [T]

Hardly anyone bothers to look for oil in the United States today. [F]

ENERGY FROM NUCLEAR FISSION (pages 16 & 17)

Reading Level (by Fry count): 12th grade (Because discussion of this topic requires the use of polysyllabic special vocabulary, this count does not accurately reflect the true reading level.)

Objectives

The student is aware that the radioactivity involves a change in the nucleus of atoms.

The student acquires a basic understanding of the workings of a fission reactor: a nucleus fissions, the motion of the resulting fission fragments produces heat, the heat can be used to run a steam turbine and generator.

The student recognizes that the nuclear fuel cycle produces wastes which require responsible long-term management.

Vocabulary

- nucleus
- electrons
- protons
- neutrons
- element
- isotopes
- radioactive decay
- chain reaction
- nuclear fission
- uranium
- breeder reactor

Background Information

Atomic Nature of Matter

Most students will have learned of atoms and particles in earlier years. The terms atomic number and mass number have deliberately not been introduced; but they might be appropriate in your classroom.

Isotopes

The two isotopes of hydrogen have their own names: deuterium (one neutron) and tritium (two neutrons). Tritium is the material used in the digital LCD watches that glow in the dark (the decay provides the energy for the glow).

The text states that most elements have isotopes because a few elements have only one isotope that is found in nature. However, if we include man-made isotopes, all chemical elements have more than one isotope.

Radioactive Decay

The radioactive decay of tritium, which is described in the text, produces a beta ray. There are other types of radioactive decay that produce other particles. The types of radiation produced are alpha particles (a helium nucleus thrown off at high velocity), beta particles, and gamma rays (which, unlike the other two, really are electromagnetic radiation.) Neutrons may also be emitted in some nuclear reactions.

When a nucleus decays, it turns into a nucleus of another chemical element, because there is a change in the number of protons. Every radioactive isotope has characteristic ways of decaying, each way producing some particular other element. The elements produced are called the daughters of the original element. The rate at which this change occurs is also characteristeric of each isotope.

The rate of decay is measured by half-life. A lesson plan on half-life will be found on page 4-3 of the appendix.

The measurement of the half-lives of naturally-occuring isotopes is the basis of the techniques used to date rocks and archeological remains. For example, when a rock is formed it probably contains a minute amount of some radioactive isotope. As time passes, the amount of this isotope decreases and the amounts of daughter isotopes increase. By comparing the two quantities, an estimate can be made of the time that has passed since the rock was formed.

Nuclear Fission

A lesson relating the energy from fission to Einstein's famous equation is provided on page 4-11 of the appendix.

While uranium nuclei can be fissioned by bombardment with neutrons, they will also fission spontaneously (a mode of radioactive decay). However, usually uranium decays in another way.

Isotopes that can be fissioned by a neutron are called fissionable; those that can be fissioned by a slow-moving neutron are called fissile. There are only three fissile isotopes and only one of these, U-235, occurs naturally.

...Some Definite Advantages

To compare the risks of various energy sources, it is necessary to compare the whole fuel cycle, not just individual parts of the system. Because nuclear power is only used to generate electricity, it seems sensible to compare it with the main presently available alternative, coal.

Radiation and Life

Very large doses of radiation kill outright, but this is not a cause for much concern (except in case of nuclear war or terrorism). Only 7 people have died of acute radiation poisoning in the entire course of U.S. nuclear energy, all of them workers.

Instead, the question is what the effect of low doses of radiation over long periods of time will be.

There are two effects:

One is somatic. For example, the survivors of Hiroshima had an increased incidence of leukemia, typically developing several years after the blast. The American women who painted luminous watch dials almost all developed bone cancer, due to the radium in the paint. (In Europe, workers doing the same job did not develop cancer, because they didn't lick the brushes to point them.) Sometimes the effects cannot be associated with a particular disease. Decades ago, radiologists had a shorter life span than other white male Americans. Gradually, standards on how much exposure was considered acceptable were made more stringent, and as this happened the lifespan of radiologists increased until it now exceeds the average of other white American males.

Another form of damage is genetic damage. In this case, the eggs or sperm of the person exposed are altered.

The faster cells are dividing, the more susceptible they are to radiation damage. That is why radiation can be used to treat fast-growing cancerous tumors. It is also why doctors are reluctant to x-ray unborn children.

In general, a given amount of radiation received in a single dose will be more harmful than if it were spread out over a period of time.

Background Radiation

Intensive efforts have been made to estimate the size of the various natural and man-made sources of radiation, mainly as a means of evaluating the effects of using nuclear power. One of the clearest ways of displaying a comparision between different sources was devised by the United Nations Scientific Committee on the Effects of Atomic Radiation, which every five years tries to summarize these effects. For each source, they estimate how many days exposure of the world population to the natural background radiation would be necessary to get the same exposure the world population gets from a particular source. So, for example, it takes 365 days of exposure to the natural background radiation to equal the exposure all humans get in one year from the natural background exposure.(1)

Source of Exposure	Days of exposure to natural background radiation needed to equal exposure to this source
One-year exposure to natural sources	365
One year of commercial air travel	0.4
Use of one year's production of phosphate fertilizers at the present production rate	0.04
One-year global production of electric energy by coal-fired power plants at the present global installed capacity (10,000,000 MW(e))	0.02
One-year exposure to radiation-emitting consumer products	3
One-year production of nuclear power at the present global installed capacity (80,000 MW(e))	0.6
One year of nuclear explosions averaged over the period 1951-1976	30
One year's use of radiation in medical diagnosis	70

This is the "dose commitment" for the population of the earth as a whole; figures would be higher for Americans because we have more consumer products, medical care, airplane flights, etc. than the average resident of Earth.

Some of the sources of radiation are:

Cosmic rays. As you go higher, this dosage increases, so that the cosmic ray dose in Denver would be twice what it would be at sea level. A cross-country round trip airplane ride adds an extra 10% from this source to the coast-dwelling traveller's annual dose.

Radiation from the radioactive elements in the ground. This varies with the geology of the place where you live. Texas is typically low and Wyoming high. Building materials also emit radiation. A person living in a stone house receives about 50% more radiation from the house than a resident of a wood house does.

Radiation from the air, which contains radioactive elements like radon.

Radiation from inside the body comes from naturally-occuring isotopes in food and water, principally potassium-40. The more you eat, the greater the dose. The lungs get by far the highest dose of any organ of the body.

The table above mentions radiation from coal plants--coal contains radioactive isotopes which are released when it is burned.

Consumer goods that produce radiation include products like watches (the largest single source), early color TV models, and smoke detectors. The latter is a good example of a trade-off in risk and benefit; the lives saved by early fire warnings greatly exceed any possible effect from the radiation emitted by these detectors.

Nuclear bombs continue to be tested in the atmosphere, contributing to the dose received from fallout. The twenty nuclear tests carried out between 1971 and 1976 increased the amount of radiation each person will receive in their lifetime (the so-called dose commitment) from fallout about 2% for people living in the Northern Hemisphere.

Medical x-rays, as can be seen, are a major source of exposure. Faster films, improved equipment, and more conservative practices are decreasing exposure from this source for most Americans.

Radioactive Wastes

The states have been very reluctant to allow a national nuclear waste depository to be established within their boundaries. One proposal has been to auction off this facility among states with suitable geology. The state that offered to store the waste for the lowest annual payment from the federal government would get the contract.

Because wastes have been created anyway by the nuclear weapons program, we will have to provide long-term storage even if we have no commercial nuclear power program.

What volume of wastes are we talking about? In a year's operation at 100% of capacity, a 1000 Mw(e) power plant will produce, after fuel reprocessing, 114 cubic feet of high-level wastes and an additional 72 cubic feet of "cladding," the metal tubes in which the fuel is packed to make fuel rods. After about a thousand years, the overall radioactivity of these high-level wastes will decay to the level of the original ore body. Of course, it is no longer safely underground, and a different set of isotopes has been created, which may be good or bad depending on how they are taken up by organisms. In addition, mining and processing the ore, operation of the reactor, and operation of the reprocessing plant result in other wastes or effluents which are less radioactive, such as 6900 gallons of intermediate-level wastes, 340,000 gallons of low-level liquid wastes, and 6900 cubic feet of buried solid wastes. The largest components of the released effluents are the noble gases xenon and krypton. In terms of volume, the reactor wastes are minuscule compared with the wastes produced by a coal-fired plant with equal capacity.

Accidents

Commercial power reactors cannot explode like a bomb. All American plants are fueled with a mixture of about 96½% uranium-238 and 3½% uranium-235. Bombs are made of 10% uranium-238 and 90% uranium-238, because to get the bomb to explode, one needs a chain reaction that proceeds very fast, before the material you want to fission is blown away. To do that as many as possible of the neutrons produced by fission must hit U-235 atoms. The uranium-238 atoms just get in the way by absorbing neutrons without fissioning. If the uranium used in a reactor were assembled into a regulation military A-bomb, the bomb would not go off. Within the reactor there is no way the two isotopes can be separated in order to concentrate the U-235. For this reason alone (there are others), light water reactors cannot explode like an A-bomb.

From the very beginning of commercial nuclear power, people have been much occupied with trying to predict the nature and frequency of occurrence of possible accidents involving nuclear power plants. The most recent effort is the government's Rasmussen report, and the critiques of it.

This is a complicated field of study but an important one, because there are risks to nuclear energy as there are with any energy source. One of the less publicized risks is financial: repairing Three Mile Island, for example, is now expected to cost a billion dollars.

Breeder

Interest in the breeder arises from the fact that over 99% of the uranium mined is U-238, which can't be used as fuel and is simply accumulating. The breeder converts this waste by-product to plutonium, which can be used as fuel. It is also much easier to make bombs of plutonium than of uranium-235, which has raised the spectre of nuclear proliferation if plutonium becomes common.

Some breeder cycles do not employ plutonium, but convert the element thorium to uranium.

Incidentally, a fast breeder produces less plutonium per year than today's light water reactors do, because the breeder is also burning up plutonium as it breeds it.

Pressurized Water Reactor

The reactor illustrated is one of the two types of Light Water Reactor (LWR) used in the United States. The other type is called the Boiling Water Reactor (often abbreviated BWR).

Activities and Discussion Topics

It does not seem possible to treat this field in a day or two. Beyond going over the contents of the reading with your class, you might wish to try some lessons. We have picked two that stand alone fairly well, if the class is motivated and has already learned about atoms and nuclei:

Half-Life of Isotopes, appendix p 4-3
Energy From Fission, appendix p 4-11

Mini-Quiz

1. What is the name of the type of reactor which uses extra neutrons to change an isotope that cannot be used as fuel into one that can be? [breeder]

2. What is the inner part of the atom called? [nucleus]

3. What is the correct term for "splitting the atom?" [nuclear fission]

4. When a reactor is operating, the rate at which it produces energy is controlled by controlling the number of what? [neutrons]

5. Energy produced in a nuclear reactor is extracted in what form? [heat]

6. What do we call it when the fissioning of one atom causes several other atoms to fission, and they cause still others to fission, and so on? [chain reaction]

7. Name the two main particles found in the nucleus. [neutron, proton]

8. Name one natural source of radiation. [Cosmic rays are mentioned in the text; there are other correct answers.]

9. A beta ray consists of what particle? [an electron]

10. Uranium 235 and plutonium 239 are both radioactive. What else do they have in common? [They can be split by slow-moving neutrons.]

True or False

The nucleus of one atom has three neutrons and two protons. The nucleus of another has two protons and two neutrons, so they are atoms of the same element. (T)

The number of protons in the nucleus is the only factor determining which chemical element it is. (T)

It is possible for some chemical elements to change into other elements. (T)

A commercial power reactor could explode like an atomic bomb. (F)

Some elements have some isotopes that are radioactive and some isotopes that are not. [T]

ENERGY FOR THE NEXT TEN THOUSAND YEARS (pages 18 & 19)

Reading Level (by Fry count): borderline between 7th and 8th grades.

Objectives

Students recognize the possibility that a transition to renewable energy resources will eventually be necessary.

Students recognize that appropriate use of renewable resources conserves other energy sources for other uses.

Students recognize that sunlight is converted to heat through absorption.

Students are aware of methods of using sunlight to meet the need for heat (for hot water and space heating) in a home.

Students are aware that heat can be transferred by circulating fluids.

Students are aware that heat can be stored through the thermal inertia of materials.

Vocabulary

solar collector
damper

Resources

Request a free set of the NSTA Fact Sheets from DOE/TIC, P.O. Box 62, Oak Ridge, TN. A Solar Energy Education Bibliography, (Expanded), which is annotated and very complete, is available for a $3.74 check made out to "Sundries" from the Center for Renewable Resources, 1001 Connecticut Ave. NW #510; Washington, D.C. 20036.

Modern Talking Picture Service (see your phone book for nearest regional office) offers a free-loan film (sponsored by Exxon) on solar architecture, Energy from the Day Star. Though the examples are upper-income homes, the possibilities are very well illustrated, and the film has no commercial message. We recommend it.

Background Information

The Need for Renewables

A point not mentioned in the text is that exploiting sunlight does not add to the earth's heat load, as do combustion, fission, and fusion. At the present time, this effect is noticeable only in the climates of cities, which are warmer than the surrounding countriside. However, if energy consumption were to continue to increase at the present rate, the heat added to the atmosphere could in time become a serious problem.

"Sunlight is the basic..." Economics and Efficiency

This section attempts to distinguish between capital costs and operating or maintenance costs.

Recent developments in plastic solar collectors for water heating provide a good example of trade-offs between cost and energy-efficiency, and illustrate the point that making improvements in efficiency regardless of the cost is not sensible. Ordinarily much more roof area is available for the collectors than is needed. On the other hand, the purchase price of the collectors is a serious obstacle. As a consequence collectors with plastic absorbers have been developed. They are easily fabricated and cheaper than collectors with metal plates, but they are also less efficient: they produce less heat per square foot. However, it can be cheaper to install a big, inefficient, plastic collector than a smaller, more efficient metal one that produces the same amount of hot water. Of course, if your demand for hot water outruns your roof area the situation is different.

Active Solar Water Heater

This is the kind of system that most people picture when they think of solar energy.

To keep things simple, the system chosen for illustration does not incorporate a heat-exchanger. It therefore would have to be made of approved sanitary materials throughout, because all parts of the system would come in contact with water people would drink. In freezing weather the system would have to drain itself automatically lest the water freeze and burst the collector.

To eliminate this risk, many systems use a heat exchanger. One loop of fluid circulates between the collector and storage tank, and anti-freeze can be added to this fluid. A heat exchanger in the storage tank keeps the antifreeze out of the drinking water while transferring the heat.

The functions of some of the labelled parts are:

Bleeder valve---used to purge air from the system.

Pressure relief valve---opens to prevent pressure increases from springing leaks in the collector plate or other parts of the system.

Check valve---allows the fluid to flow in only one direction. If fluid were allowed to flow in either direction, then at night when the collector was colder than the water in storage, convection would cause the warm water from the tank to flow up to the collector and cool.

This phenomenon, called thermosiphoning, is exploited in passive solar water heating systems. These need no pump, but the storage tank must be higher than the collector, so that heated water can rise to it. These are the most cost-effective of heaters, but they are seldom installed because of the awkward location of the storage tank.

Active Solar Space Heating

Note that the system has basically the same components as the water heater: a collector, a fluid which is used as a means of transferring heat (air), and a thermal mass (the bed of rocks).

Passive Solar Space Heating

This is an extremely important topic, which can probably have a greater impact on the nation's energy use than any of the active solar systems.

Passive solar has the same three elements as active, but the house itself is the collector and the thermal storage mass. Those three elements are:

some way of collecting sunlight as heat
some way of storing heat
some way of transferring the heat to where we want it.

The house pictured uses what is called a Trombe Wall. Sunlight entering a glass window-wall strikes a massive wall and is converted to heat. The heat is stored by virtue of the heat-retaining properties of the masonry of which the wall is made. The heat is transferred to living quarters inside by radiation from the inside surface of the wall, which is not controlled but will be fairly even throughout the day because of the wall's thermal inertia. It is also transferred by convection currents through openings at the top and bottom of the wall, and this circulation can be controlled.

The solar greenhouse is similiar to the Trombe Wall. It differs from from an ordinary greenhouse in incorporating large thermal mass.

Passive design can also provide ventilation by arranging openings in the house walls to take advantage of prevailing winds. Even where there is little window, architects can take advantage of convection currents within a house to exhaust the hotter air.

An essential part of any passive solar design is thorough insulation.

We think the best book so far for teachers who want to learn more about passive solar is The Passive Solar Energy Book, by Edward Mazria. (softbound edition, $10.95 from Rodale Press, Emmaus, PA.) Highly recommended.

Plants

In many parts of the world, plants are currently the main source of fuel. In fact, for much of the earth's population, the present energy crisis is the firewood crisis, caused by deforestation; and not our petroleum crisis.

Several United States cities are currently using plants as fuel, but the fuel mainly comes from wastes and thus is subsidized by previous uses. Several cities recover methane from fermentation of sewage or of materials in landfills.

Photovoltaic Cells

They last for decades and are maintenance-free. Most of those in current use are made of thin slices of huge crystals of silicon. Costs have fallen dramatically since they were first produced for the space program. If the cost of the crystal can be lowered through some mass-production technique, such cells will become cheaper. Meanwhile, other workers are searching for alternative ways of directly converting sunlight to electricity or fuel. Some devices use semiconductor substances other than silicon. Some use many tiny silicon crystals on a panel submerged in a solution to produce hydrogen by a process like electrolysis. Still other researchers are trying to duplicate photosynthetic-like processes in a test tube. Any or all of these approaches may lead to a breakthrough.

Windmills

Most students think of Holland when they think of windmills, but as a matter of fact our plains might never have been settled without the windmills which provided water for irrigation and livestock before rural electrification.

A fine free-loan film on wind, Gusts of Power, (14 min) is available from the DOE/TIC, P.O. Box 62; Oak Ridge, TN.

Geothermal

Hot steam like that found in the Geysers field near San Francisco is rare. Warm water, while it not suitable for the production of electricity, is being used to warm schools, houses, and commercial greenhouses in various parts of the country. Experiments are going on to find ways of using hot dry rock.

Geothermal power is often polluting (hydrogen sulfide, radon) if air pollution abatement equipment is not used.

Fusion

Contrary to a common misconception, fusion energy using the reactions presently contemplated does produce radioactive wastes, because the escaping neutrons irradiate the reactor materials and create radioactive isotopes. It also appears that fusion reactors, if they can be built, will be much larger and more expensive than fission reactors.

Activities and Discussion Topics

If you have not already used the bead fling lesson on depletion of fossil fuels (appendix p 3-37), you may wish to consider using it before beginning the discussion of renewables.

I. What are renewables?

II. Discuss role of renewables. Why might people be interested in their development?

Possible responses:
increase self-reliance, personal or national security
save money
get ready for anticipated future

III. Study the diagram of the active solar water heater.

1. Where is the sunlight converted to heat?
2. How is the heat circulated?
3. Where is the heat stored?
4. What does the control box do?

IV. Study the diagram of the active solar space heater.

1. Where is the sunlight converted to heat?
2. How is the heat moved from place to place?
3. Where is the heat stored?
4. What are the dampers used for? How would they be set in each of the following situations (to facilitate reference to them, ask students to number the dampers in their booklets):
    a. The sun is shining brightly but the house is warm enough.
    b. It is night. The house needs heat.
    c. The sun is shining and the house needs heat.

We have chosen to include in the appendix the sequence of activities on the movement of the sun. Understanding the sun's movement is fundamental to passive solar design, and less importantly, to the use of concentrating collectors. The sequence begins by establishing the concepts of bearing (app p 5-3) and altitude (p 5-5). Making a record of the sun's movement for a day (app p 5-7) and then transferring it to Cartesian coordinates is a hands-on way of explaining the meaning of a sun angle chart. After students see how they could do it for themselves if they had a year to make observations, they are given a sun angle chart for their latitude. These lessons lead to passive solar design. Here, one example of the transition to passive solar will have to suffice.

Take the sun angle chart for the even latitude nearest to your own latitude (please have it in hand as you read this explanation). Suppose you have a room with south-facing windows. It is too warm in the summer, too cold in the winter. What can we do?

If we look at the chart, we see that the winter sun is much lower in the sky than the summer sun. Draw a line through the chart so that it is just above the sun at noon on March 21. Suppose we make an awning that hangs down just this far. On March 21, the sun will shine into our room all day long. That's good, because we're too cold. But on June 21, the sun will disappear behind the awning early in the morning and stay there until late afternoon. That's good, because in June we're too hot. From the sun angle chart, we can tell exactly where to put our overhangs.

Mini-Quiz

1. How is heat transferred from a solar collector into a house? [by a circulating fluid like water or air]

2. What keeps a solar-heated home warm when the sun isn't shining? [heat is taken from storage]

3. Name a device that converts sunlight directly to electricity. [photovoltaic cell]

4. Name a material that would be good for storing heat in a solar house heating system. [water, rock, masonry]

5. What is the name of the type of solar heating that does not use any pumps, and uses the house itself as the collector? [passive solar heating]

6. Around 1900, solar collectors were popular in some parts of the country. Why was their use largely discontinued? [Petroleum and gas were cheap.]

7. It is easiest to turn sunlight into what other kind of energy? [heat]

8. What is the name of the kind of reaction from which the sun gets its energy? [fusion]

9. What is the name of the kind of energy we get from hot rocks in the earth? [geothermal energy]

10. What is the name of a valve in a chimney or air duct that can stop the flow of air? [a damper]

True or False?

North-facing windows help to warm a house. (F)

More than half of the nergy used in homes is used to heat air or water. [T]

An active solar water heating system needs electricity to operate. [T]

ENERGY...THE MORE WE HAVE...THE MORE WE USE... THE MORE WE WANT (pages 20 & 21)

Reading Level (by Fry count): 8th grade

Objectives

Students are aware of the large per capita increase in energy consumption by Americans since 1900.

Students are aware that there has been a shift in energy sources.

Background Information

1700

. The Iroquois were chosen rather than the colonists in the year 1700 because they represent a pre-machine, pre-fossil fuel society. Such societies still exist; in fact, people like the Tasaday of the Philippines are today less advanced technologically than the Iroquois were in 1700.

1800

By 1800 Americans in the large Atlantic coast cities like Philadelphia and New York had begun to use coal, but the amount was too small to show up on a graph at this scale. Water power was also in use, especially in New England, and New York had some windmills. None of these provided enough energy to be visible on a graph at this scale. Wood was far and away the primary energy source.

Contrary to a popular impression, Americans of the late colonial period were not frugal in their use of energy, if we compare them to Europeans of the same period. The chief reason for this high level of consumption was the national project: making farms out of a virgin wilderness. To do this, trees had to be cut down and disposed of. On the frontier, all the firewood one wanted could be had for the labor of cutting it, with the grateful thanks of the landowner. Another reason energy consumption was so high was that pioneers lacked capital. They did not have money to buy iron stoves, glass for windows, oil and lamps, or other goods that would have made possible less energy-intensive ways of doing things. An enormous fire in an inefficient open fireplace was lamp, heater, and stove to most colonials.

By 1800, this was changing, and the change was first felt in cities. Wood was getting dearer; housing better; stoves more common. The nation was poised for industrial expansion.

1900

By 1900 America was essentially an industrial nation. Coal was the primary energy source. Petroleum was primarily a fuel for lighting; automobiles were curiosities.

1979

Notice that for 1979, the Homes, Stores, Offices category is subdivided into Space Heating, Cooking, Water Heating, Refrigeration.

Exponential Growth

Turn the student booklet sideways, so that the years are on the bottom. Now the end of each line represents per capita energy consumption in some particular year. If we imagine a line drawn through the ends of the lines, its general shape is that of an upward sloping curve. (If we had figures for more years, we would have the same general shape plus a lot of squiggles for events like the Great Depression.) If each year, each person had increased their energy consumption by a fixed amount, say an additional 100 gallons of gasoline, this curve would be a straight line. It is not a straight line. This shows that each year's sonsupmtion is some multiple of past consumption. For example, for many years, consumption of electricity increased around 7% a year. (That steady growth made planning pretty easy for utilities. Now the growth rate is down, and what is worse for the planners, it has become very hard to predict what it will be a decade ahead.)

The difficulty with growth rates like this is that the more time passes, the faster things happen. It is like the adviser who got the king to pay him one grain of wheat on the first square of the chessboard, two on the second, four on the third, and so on. There was not enough wheat in the world to pay such a debt. If you stop and think about it, you will see that such growth cannot go on forever; the only question is how long before we run out of whatever necessity is in shortest supply, and what we can find to substitute for it.

Activities and Discussion Topics

Reading a Bar Chart

1. First confirm that the students understand how to read bar charts in which there are bars within bars.

Tell the class pages 20 & 21 are a kind of bar graph, laid on its side. Have students identify the key or legend. Ask them to write on the bars the names of the energy sources in 1800. Now write the names of the uses in 1979. If there isn't room to write out the word on the bar, write it in the surrounding white space and connect the word to the bar with a line. Use this deskwork to confirm that students understand how to use the key.

2. Now confirm that students are able to use a scale.

Ask them to find the scale at the top of the graph. The vertical lines are one centimeter apart.

How many Btu's did an average Iroquois use in 1700? [10 million]

How many Btu were used for transportation in 1900? [30 million Btu per person]

3. Ask students to use a metric ruler to measure the length of the bar for transportation in 1979. How many Btu does it represent? [about 8,900,000 Btu]

4. A worksheet is provided on page 49 which students may be asked to complete in class or as homework.

Discussing Our Energy History

In the appendix of this book is a selection of readings on America's Wood Age which may be helpful in bringing America's energy history to life for your students. Each is accompanied by study questions for students. Here are some points for class discussion:

- Captain John Smith: Off to the Wilderness (app p 6-3)
  - What were the available energy sources?
- Benjamin Franklin: The Newly Invented Fireplace (app p 6-7)
  - What was the fuel situation?
  - What was Franklin's response?
- Captain Edward Marryat: Transportation in America, 1830
- Marryat: Salt
  - Can wood be a fuel for industry?
- Marryat: No Midwestern Industry (app p 6-22)
  - What energy sources were used for manufacturing in the 1830s?
  - How do people make mistakes in foretelling the future?
- Mark Twain: The End of Steamboating Days (app p 6-23)
  - Why did the steamboat decline?
  - Why did the woodyard man vanish?
- Laura Ingalls Wilder: Sudden Storm (6-29, Candlemaking (6-32), Icecutting (6-35).
    - Compare how the rural Americans got heat, light and cold in the late 1800s and how we do it today.
  - Talking about Horses (6-38), A New Plow (6-39), A Sewing Machine (6-41)
    - How did machines enable people to make better use of the muscle power available to them?
  - Mr. Ingalls Threshes (6-43), Mr. Wilder Threshes (6-46)
    - How do people's attitudes to labor-saving machines differ?
    - Do people have different attitudes today?

Critical Thinking

What might be some of difficulties of gathering statistics like these?

Did the Iroquois keep energy consumption statistics? How could an anthropologist go about estimating the energy consumption of a vanished society? What kinds of records might the Americans have kept in 1800?
How would an historian go about estimating energy consumption in earlier periods?

Which energy sources might be hardest to keep track of today? Does that mean they are undercounted?

Mini-Quiz

1. What was the chief fuel in 1800? [wood]

2. What was the chief fuel in 1900? [coal]

3. What was the chief fuel in 1979? [petroleum]

4. In 1800, which used more energy, homes and stores, or industry? [homes and stores]

5. In 1979, which used more energy in homes, stores, and offices: space heating or water heating? [space heating]

True or False

Between 1900 and 1979, there was a great increase in the proportion of the percentage of total national energy consumption used by industry. [False]

Worksheet

Turn to page 20 of your booklet. Circle the right answers or fill in the blank.

1. In 1900, which used more energy per person, transportation or industry?

2. In 1979, which used more energy per person, transportation or industry?

3. Which produced more energy per person in 1900, hydropower or wood?

4. In 1979, which used more energy in homes, cooking or water heating?

5. Which energy sources were important enough to show up in 1900 but were not in 1800?______________________________

6. Which energy sources were important enough to show up in 1979 but did not show up in 1900? ______________________________

****

Using a Scale

To answer these questions, you will need a ruler marked in millimeters. Write the answers in the space provided.

1. Find the scale. It says that 1 centimeter = ____________ Btu.

2. Then 1 millimeter will equal ____________________ Btu.

3. A bar 3 centimeters long represent would represent ________ Btu.

4. In 1800, coal supplied ____________________ Btu.

5. In 1900, industry used ____________________ Btu.

6. In 1979, industry used ____________________ Btu.

****

Comparing Numbers

1. The people in 1800 used ______times more energy per person than the Iroquois did.

2. About ______per cent of the energy used in 1979 was used for cooking.

ENERGY PRODUCTION & CONSUMPTION...
HERE IT COMES, THERE IT GOES (pages 22 & 23)

Reading Level (by Fry count): 8th grade

Objectives

The student is aware of the relative magnitude of present-day energy sources and uses.

The student is aware of which energy sources presently support particular uses, such as dependence of transportation on petroleum and extensive use of coal for electrical generation.

Background Information

This chart is based on the most recent data available at the time of publication. You may wish to discuss with students why the most recent data would be for 1979, i.e., it takes time to collect and compile statistics. In the same vein, you might wish to discuss differences in the difficulty of monitoring different kinds of energy sources and uses: e.g., it is relatively easy to find out how much electricity households use, but very difficult to find out how much firewood.

The statistics on which this chart is based lump agricultural activities with other industrial and commerical energy use. Agriculture is estimated to use about 17% of total U.S. energy consumption (earlier estimates were around 12%, including about 22% of all electricity consumed). A 1974 study divided estimated annual per capita energy use for agriculture as follows:

agriculture (farm, fertilizer, etc)	5.8 million Btu
food processing	10.6
transportation	0.9
wholesale and retail trade	5.2
home	9.9
total	32.4

Some students make the mistake of thinking that the top band flowing into a block must power the top line out. For example, referring to the "Transportation" block, powering pipelines is NOT exclusively the job of natural gas; and similiarly in "Residential," electricity is obviously not just used for space heating.

Some of the phrases on the chart may need interpretation:

"Extraction loss and reservoir reprocessing" includes such things as oil spills and the use of petroleum or its products to maintain production in a field.

"NGPL" is natural gas plant liquids, liquids which condense out of natural gas during its processing.

"Space heating" means, for example, heating homes or offices for purposes of comfort.

In the industrial blocks:

"Primary metals" are industries that convert metal from ore to the form in which they go to fabricators.

"Process steam" is steam which provides heat and sometimes water itself for a process. This does not include, for example, the steam produced in an electric power plant.

"Electric drive" is electric motors.

"Electrolytic process" are, for example, the electrolytic refining of aluminum and copper.

"Feed stock" is coal, oil, and gas used to make substances like plastic or lubricating oil.

Activities and Discussion Topics

If your class is quite familiar with graphing, you may want to move immediately to examining the diagram. Other classes may benefit from approaching the flow diagram through some simpler diagrams of the same type. A worksheet for doing this begins on page 54.

Worksheets for examining the flow diagram itself are provided on pages 56, 57, and 58. Before assigning the sheets, be sure students understand that in the graph all energy is measured in Btu's, a unit of heat. The sources are not measured in physical units like gallons of gasoline or tons of coal. This way, we can compare different sources. (On the other hand, 100 Btu's of one source may be inherently more useful than 100 Btu's of another.)

The names of the sheets and the topics they treat are:

Energy Sources in the United States

The exercise asks students to compare the contribution of various energy sources, and the relative sizes of the different uses made of a source.

Energy Uses in the United States

This exercise asks students to compares the amounts of energy needed for various purposes.

Getting the Numbers Right

The exercise provides practice in the use of a scale and in computing percentages. It reinforces points made in the previous sheets but adds nothing new.

Efficiency of Energy Use in the United States

The purpose of this sheet is to bring out the large potential for conservation available through increased efficiency. For example, the waste heat consequent to the generation of electricity might be put to some use, perhaps through cogeneration.

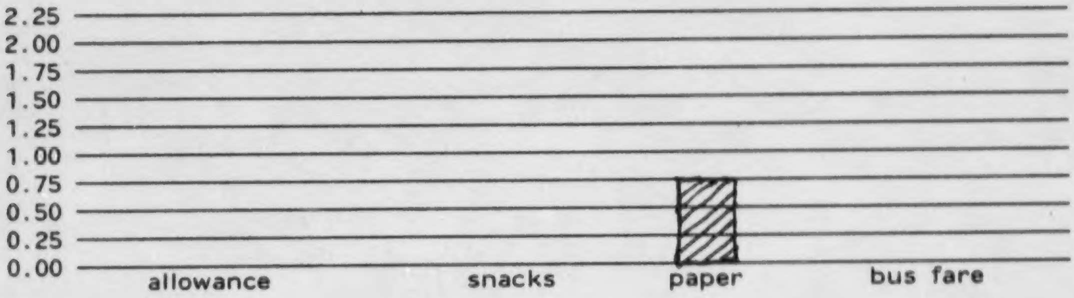
Study of this flow chart can lead into having the students contruct a similiar flow chart for their own household. Forms for this purpose are on appendix page 6-69 and 6-70.

Worksheet

A Kind of Graphing

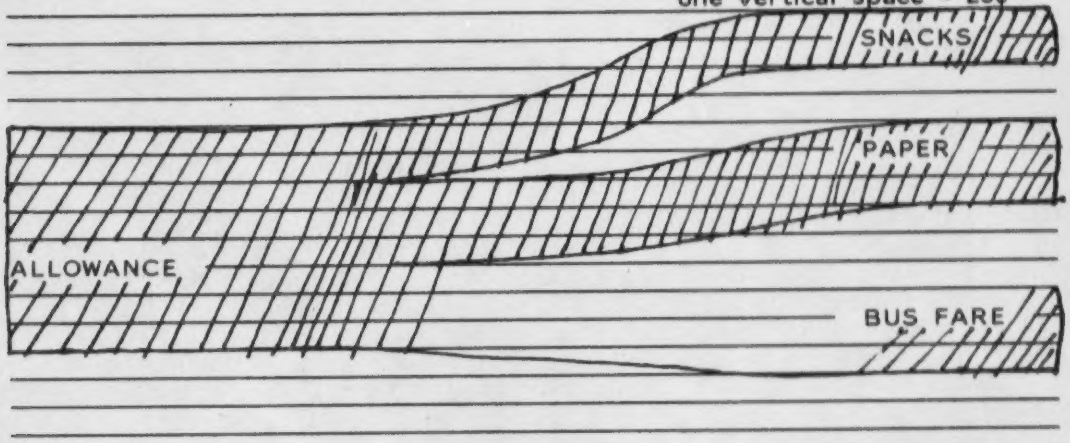
In this activity you will learn about a new kind of graph, which is related to a bar graph.

Part One: A junior high student got a $2 a week allowance. He spent it on snacks (50¢), notepaper for school (75¢) and bus fare (75¢). Using the form below, make a bar chart of Bill's income and expenses. One of the bars is done for you.



The amount Bill gets as allowance is exactly as large as his total expenses. After all, the money goes in and out of the same pocket. We can make a new chart that shows this. Some of the lines and shading are missing. Add them.

one vertical space = 25¢



Part Two:

Moving up in the world, Bill gets a job and earns $15 a week in addition to the $2 allowance. Now he spends it on a movie ($2), snacks ($1), bus fare ($1), school supplies ($2) and he saves $11 for a motorcycle. Make a bar chart of his income and expenses.

$20

$15

$10

allowance job savings movie snacks school supplies

Now make a diagram of his new situation by adding the missing lines and shading with your pencil.

one vertical space = $1

SAVINGS

ALLOWANCE

MOVIE

JOB

SNACKS

SCHOOL SUPPLIES

Activity Sheet

Energy Sources in the United States

Answer these questions by studying the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You may need to use a ruler, preferably one marked in millimeters. Write the answers to the questions on a separate sheet of paper, numbering your answers.

1. This diagram provides a picture of United States energy use in what year?

2. What is the largest single source of energy used in the United States?

3. What was the largest single source of domestically-produced energy (not counting the imported energy)?

4. What were the three largest sources of the energy used to generate electricity?

5. What energy source provided most of the energy used in transportation?

6. What energy source provided most of the energy used in the home?

7. What form of energy did we export the most of?

8. What form of energy did we import the most of?

9. What was the largest single use for coal?

10. What was the largest single use for petroleum?

11. What was the largest single use for natural gas?

12. Which provided the greater amount of energy, coal mined underground or surface-mined coal?

13. Was more natural gas obtained from oil wells or from wells drilled specifically for gas?

14. Which used more natural gas, homes or industry?

15. Aside from its use for generating electricity, only one sector consumed significant amounts of coal. Which one?

16. Which of the three energy-using sectors used too little electricity for it to be visible on the diagram?

Activity Sheet

Energy Uses in the United States

Answer these questions by studying the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You may need a ruler, preferably one marked in millimeters. Write the answers to the the questions on a separate sheet of paper, numbering your answers.

1. Of all industrial uses of energy (except "other"), which two used the most energy?

2. Which used more energy, homes (residential) or transportation?

3. What mode of transport used the most energy?

4. Which used more energy, railroads or airplanes?

5. Which used more energy, trucks or railroads?

6. Is it possible to tell from this diagram which used less energy to move one ton of freight one mile, an airplane, a truck, or a railroad? Explain your answer.

7. List in order the two largest uses of energy in residences, not including "other".

8. What was the largest single use of energy in the commercial sector?

9. Two other industries used about the same amount of energy as the concrete, stone, clay and glass industry did. What are the other two?

10. Which used more energy, running automobiles or heating homes?

Activity Sheet

Getting the Numbers Right

Answer these questions by measuring the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You will need a ruler marked in millimeters. Write the answers to the questions on a separate sheet of paper. Show your calculations, if any.

Using a Scale Factor

1. How many quadrillion BTU did petroleum provide?

2. How many quadrillion Btu did natural gas provide?

3. How many quadrillion Btu did the United States use in all in 1979?

Calculating Percentages

Carry your answers out to the nearest whole percent.

1. What percentage of the energy used in homes was used for space heating and water heating together?

2. What percentage of the energy used in transportation was used by automobiles?

3. What percentage of the energy provided by natural gas was used to generate electricity?

4. Of the total electricity generated, what part of it came from natural gas?

5. What percentage of the energy used in industry was used to run electric motors ("electric drive") and for chemical processes using electricity (like the "electrolytic process" for producing aluminum)?

6. What percentage of the energy used in industry was used in petroleum refining?

Activity Sheet

Efficiency of Energy Use in the United States

Answer these questions by studying the energy flow diagram on pages twenty-two and twenty-three of your Energy 80 booklet. You may need to use a ruler, preferably one marked in millimeters. Answer the questions on a separate sheet of paper, numbering the answers.

The Red Arrows

In the diagram, waste heat is colored red for emphasis. All energy eventually turns to heat. Every time we use energy we convert it from one form to another, and part of it changes to heat whether we want heat or not. The energy used at home, in stores and industry, eventually becomes heat. Even the energy of a moving automobile is changed to heat when we put on the brakes. Finding uses for this "waste" heat is one of the most promising ways of getting more use out of the energy we use.

1. Is energy used more efficiently in transportation or in homes? Why do you think this is so?.

2. Compare the efficiency of nuclear power and hydropower in generating electricity. What accounts for the difference?

3. What is the overall efficiency, for the 1979 mix of sources, of the electrical generation process?

4. What are some uses that could be made of this waste heat?

Answers to Activity Sheet Questions

Energy Sources in the United States

1. 1979
2. petroleum
3. natural gas
4. coal, petroleum, natural gas
5. petroleum
6. natural gas
7. coal
8. petroleum
9. generating electricity
10. transportation
11. industrial
12. surface-mined coal
13. wells drilled for gas
14. industry
15. industry, industrial
16. transportation

Energy Uses in the United States

1. chemical industry, primary metals
2. transportation
3. automobile
4. airplanes
5. trucks
6. No, it is not possible. The chart tells us only the total amount of energy used in particular ways, not how much was accomplished by using that energy.
7. space heating, water heating
8. space heating
9. food (processing), paper industry
10. automobiles

Getting the Numbers Right

Using a Scale Factor

A range is suggested for the right answer because students can only be expected to measure with a certain precision.

1. 67 or 68 quadrillion Btu.
2. 33 or 34 quadrillion Btu.
3. 120 or 121 quadrillion Btu.

Calculating Percentages

1. 69%
2. 52%
3. 19%
4. 20%
5. 39%
6. 13%

Efficiency of Energy Use in the United States

1. Homes. Much of the energy use in homes is converting other forms of energy to heat, which can be done at very high efficiencies. In transportation, other forms of energy are converted to work in lightweight machines, and the efficiency cannot be as good.

2. The hydropower is shown being converted to electricity at an efficiency of almost 100%. This is really only the efficiency of the generator; we don't take into account the energy lost in the weather, the eroding of stream beds, and other places in the water cycle. Nuclear power, like the other major sources of electricity, depends on a heat engine, the turbine. Heat engines cannot change 100% of the heat to motion. (Actually, nuclear reactors are a little less efficient than fossil-fuel fired power plants, because the reactor doesn't reach as high a temperature as a boiler does.)

3. 32%. (10 divided by 10+21)

4. It could be used to heat nearby homes, businesses, or stores, to raise warm-water fish, to heat heavy oil underground, and so forth.

INVESTING IN ENERGY: MONEY OUT, MONEY IN (pages 24 & 25)

Reading Level (by Fry count): 8th grade (excluding tables)

Objectives

The student realizes that economic analysis may be used to prioritize investments in energy conservation and production.

Resources

A good low-cost three-week unit on energy and economics is Energy Tradeoffs in the Marketplace, prepared by the Washington State Council of Economic Education. Contact Donald Wentworth, Center for Economic Education; Pacific Lutheran University; Tacoma, Washington 98447 for up-to-date information on its availability. A PEEC module, Energy as an Investment Choice, (grades 9-12) is available free from DOE/TIC, P.O. Box 62; Oak Ridge, TN.

Background Information

Why a 9% Interest Rate?

In the examples, a 9% interest paid by the bank is assumed in order to use a market rate of interest, not a rate set by law, as most rates offered by banks and savings institutions are.

When there is no inflation, the market interest rate has usually been observed to be about 3%. If the rate of inflation is 7% (as the examples explicitly assume), one would expect to be able to loan funds and receive a 10% rate of return. In fact, at the time of writing the prime rate was at 20% and money market accounts paid 16% interest.

The table on the nest page may be made into an overhead transparency to show year by year what happen to the money.

In unit 7 of the appendix will be found a few consumer education lessons, one on appliance labelling and one on incentives to conserve. As a sample of next year's lessons, we have also included masters for our own play money, in hopes it might be useful to you for your own simulations in economics.

Activities and Discussion Topics

If students take away only one idea from this page, it should be that there are rational ways of choosing what the best investment is. A corollary is that once you have figured out what is most likely to bring the greatest return, taking that action is what is likliest to make it possible for you to do the alternatives as well.

Perhaps the best way of reviewing this spread is to work out the two cases on the chalkboard with the students' help. You can follow this by trying some real-life local examples. Utilities and building supply yards often have literature with estaimates of local costs and savings for various steps. Choose projects appropriate to the homes of the students.

SAVINGS

Year	$ at Beginning	Interest	Money at End
1	50,000		
2		4,905	59,405
3		5,346.45	64,751.45
4		5,827.63	70,579.08
5		6,352.12	76,931.20
6		6,923.81	83,855.01
7		7,546.95	91,401.96
8		8,226.18	99,628.13
9		8,966.53	100,594.66
10		9,773.52	118,368.18
11		10,653.14	129,021.32
12		11,611.92	140,633.24
13		12,656.99	153,290.23
14		13,796.12	167,290.35
15		15,037.77	197,161.89
16		17,744.57	214,906.47
17		19,341.58	234,248.05
18		21,082.32	255,330.37
19		22,979.73	278,310.10
20		25,047.91	303,358.10
21		27,302.22	330,660.24
22		29,759.42	360,419.66
23		32,437.77	392,857.43
24		35,357.17	428,214.60
25		38,539.14	466,753.91

BUYING ENERGY ABROAD (pages 26 & 27)

Reading Level (by Fry count): 9th grade

Objectives

Students identify petroleum as the leading commodity in international trade.

Students recognize that we are buying about half of our petroleum abroad.

Students recognize that one cannot buy more than one sells indefinitely.

Students suggest some difficulties our large dependence on foreign supplies might create.

Vocabulary

exports
imports
[balance of trade*]
Middle East
[Arab Oil Embargo of 1973*]

*Words or phrases not occurring in reading but useful in discussion.

Background Information

14.7% of 1978 world trade, by value, was petroleum. For comparision's sake, according to United Nations' statistics the next nine most valuable categories of goods traded were:

motor vehicles	6.8%	electrical machinery	1.9%
non-electric machines	3.6%	telecommunications equip	1.5%
iron and steel	3.1%	organic chemicals	1.5%
clothing	2.0%	non-electric power machinery	1.4%

So petroleum trade is more than twice as valuable as the next most valuable item, motor vehicles.

In general, trade between nations enables goods to be supplied at the lowest possible cost, by the most efficient producer. If the Middle East will provide oil at a lower price than domestic production can, it benefits our economy to have access to the least costly source of energy. But, because the good being supplied is energy, on which most aspects of the economy hinge, other considerations also become important.

1) National security. Petroleum is the lifeblood of our economy as presently constituted, especially the transportation sector, and an interruption of supply could be catastrophic.

2) A severe balance of trade deficit.

Is OPEC Doing Us a Favor or Robbing Us?

As the oil-producing nations have often pointed out, it is not necessarily in their interest to sell us oil now. Many of the oil-exporting nations are currently receiving much more income from oil than they can spend in developing their countries. The left-over money must be invested. On the other hand, maybe they could make more money by cutting back petroleum production, leaving the oil in the ground. Since less oil would be available, that would raise oil prices, which are rising anyway. The value of the oil ten years from now (it would certainly still be there) might be greater than the value of the oil now plus the money they could make in ten years from investing them money from a sale now.

The Oil Embargo of 1973

A common misstatement is that OPEC created the oil embargo of 1973 during the Arab-Israeli War. Actually, the embargo was only by the Arab members of the organization. The non-Arab states continued to supply oil. In addition, at the beginning only the United States and the Netherlands were embargoed. Later Rhodesia, Portugal, and South Africa were added.

Activities and Discussion Topics

1. How many different colors of arrows are there? Find the legend that explains the meaning of the colors.

What does the width of the arrows indicate?

Which arrows are wider, the red petroleum arrows or the black gas arrows? Why?

2. Identify the countries or regions from which the larger red arrows are coming. Write their names on the map.

3. Identify the countries or regions to which the oil is going. Write their names on the map.

4. The oil arrows reaching Japan and the U.S. are about the same size. Does this mean they consume the same amount of oil? Why not?

Be sure the class understands that the map does not show oil or gas that a country produced and used itself, only flows between countries.

5. The chart on pages 22 & 23 shows that in our country gas provides about half the energy oil does. Can you think of any reasons why the trade in natural gas is so much smaller than the trade in oil?

Note the black arrows going from Alaska and Indonesia to Japan, and from Algeria to Europe and the eastern U.S.. This is Liquified Natural Gas (LNG), carried in tankers at temperatures below minus 260° F. (Some of the Algeria--U.S. shipments have been cut off because of a price dispute.)

6. Where do you think the arrows would go for these commodities:

motor vehicles	wood
wheat	iron and steel

7. Could the amount of oil we import each year decrease at the same time as the amount of money spent on foreign oil increases? How?

> Compare this situation with the situation of a family that practices conservation but sees their utility bill rise. What would happen if they didn't practise conservation?

8. The drawing shows the oil exporters with dollars. Why would they be willing to take dollars for their oil? What are the dollars good for?

> You can make discussion of this topic more concrete by having some foreign currency. Show the students the money and ask if the local hamburger stand would accept it. Who might? Why?

10. What does our community produce to trade with people overseas for the petroleum we are using?

> Make a rough estimate of the value of the imported oil used by your community by multiplying the number of people times 12 barrels (a national average per capita consumption of imported oil) times $38, the marginal price per barrel in January, 1981. Your community would have to export goods or services, or obtain foreign investment of this amount to balance oil imports (and don't forget cars, clothing, and everything else we import).

11. Suppose all the candy bar makers got together and agreed to raise the price of candy bars to $20. What would happen to sales of candy bars?

> There are limits to what a cartel or monopoly can do. These limits are set by the demand curve: how much buyers are willing to buy at different prices. OPEC would not be able to raise the price of oil if demand were not so great. Even if there were no OPEC, oil prices would rise because world demand has been rising. Can you think of any reasons why world demand for oil might have risen in the last twenty years?

Mini-Quiz

1. What is the biggest item in international trade? [oil]

2. What country buys the most oil? [the United States]

3. From what country do we import the most oil? [Saudi Arabia]

4. Name an African nation from which we import oil. [Nigeria]

5. About how much of the oil we consume is imported? [about half]*

6. About how much did we spend on imported oil in 1980? [80 billion dollars]

* Review question on related topic introduced in an earlier lesson and reviewed in class discussion during this lesson.

SAVING ENERGY DOLLARS AT HOME (pages 28 & 29)

Reading Level (by Fry count): 6th grade

Objectives

The student recognizes that the control of heat is the single most important means of home energy saving.

The student learns a number of techniques for controlling heat.

The student becomes aware of some unnecessary uses of energy in the household, such as forcing air through dirty filters, lighting and heating unused areas, and using hot water for all laundry.

Vocabulary

space heating
weatherstripping
caulking
insulation

Useful Demonstration Materials

insulation samples
caulking gun
piece of weatherstripping
furnace filter

Resources

Request free copies of the pamphlets Tips for Energy-Savers (EDM-064, also available in Spanish as EDM-065) and Low-Cost, No-Cost Energy Savers (CS-330) from DOE/TIC, P.O. Box 62, Oak Ridge,TN. The most practical booklet of ideas for low-income families is Save Energy: Save Money, distributed by the Office of Public Affairs, Community Services Administration, Washington, DC 20506.

Background Information

Too often we focus on forms of conservation which are largely symbolic, like giving up the electric toothbrush. This is great, but actually, most of the energy consumed in the house goes to make raw heat. Obtaining this heat more efficiently and minimizing its loss is not as dramatic as a gadget diet, takes a lot more thought, costs more money, and requires continuing commitment. But the savings that can be achieved far exceed the toothbrush savings, even including the indirect energy costs of manufacturing such gadgets. (See appendix page 1-38)

We also believe the best way of teaching conservation techniques is to teach physical principles along with the techniques. Techniques change. In ten years some new kind of insulation may make all else obsolete, but houses will still lose heat by conduction, infiltration, and radiation. The spread treats conservation as a series of tips. We think students will retain the concepts longer if you are able to relate these tips to what the students know about heat flow, for example.

Activities and Discussion Questions

1. Look at the "Residential" block on page 23. What are the largest blocks? [Answer: the yellow "space heating;" the orange "water heating;" and the blue "other."] Together, how much of the total do space heating and water heating take up?]Answer: over half.]

This tells us that in the average home, space heating and water heating use most of the energy consumed. Is this true in your home? How could you find out?

2. What are some of the different ways heat can escape from a home?

One is conduction. Appendix p 8-5 provides a worksheet for calculating the heat escaping from windows. Appendix p 8-7 outlines an activity at home investigating insulation.

3. Energy can be conserved at home by using energy-efficient appliances. A lesson on the federally-mandated appliance labelling program will be found on appendix page 7-3.

Some Follow-up Activities at Home

1. With a parent's help, do an experiment to compare the cleaning power of hot and cold water in doing your family's laundry.

2. If you have a gas water heater, with a parent's help learn how to drain the sediment from the bottom of the tank. Let it settle and bring a bottlefull to school to show the class.

3. If you have a forced air heating system, with a parent's help find the filter and learn how to remove and examine it. Is it clogged? If it is, replace it and bring the dirty one to school to show the class.

4. If you have a leaky faucet, use a cup to catch the drips and calculate how many gallons of water are being lost in a day. (1 gallon = 16 cups).

5. If you have a dishwasher, with the help of a parent see if you can air dry the dishes by stopping the dry cycle and leaving the dishwasher door open over night. Do the dishes dry satisfactorily?

6. With a parent's help, try to think of at least two ways you could keep heat from escaping through your windows in the winter.

Some Consumer Research Projects

Assign groups of students to investigate and report on the following topics. Most of the research can be done by interviewing salespeople in stores, collecting product literature, and reading advertisements.

How do pilotless gas ranges, furnaces, and water heaters work?

Do gas water heaters really differ much in energy efficiency?

How does one read an appliance energy efficiency label?

How is caulking done? What kinds of caulk are available and how do they differ?

What is weatherstripping? What does it look like and how is it applied?

What are the different types of insulation?

Mini-Quiz

1. What is the biggest use of energy in the average home? [space heating]

2. What part of the house lets heat out most readily? [windows]

3. How do we stop warm air from escaping, or cold air form entering the house between the door and the door frame, or the window and the window frame? [by using weatherstripping]

4. How can you tell if the gasket on your refrigerator door is good? [It's good if it stops a playing card.]

True or False?

Lighting and heating a home evenly saves energy. [F]

CONSERVATION: ENERGY & HAPPINESS (pages 30 & 31)

Reading Level (by Fry count): 8th grade

Objectives

The student examines the relation between energy consumption and the quality of life.

Background Information

To many students, rising energy costs and the prospect of lower personal consumption imply a future lifestyle which may be far less satisfying than the one they now enjoy, or that their parents have enjoyed. To what extent does well-being, or the difficult to define "quality of life," depend on energy consumption? Or, put in its baldest form, is it true that the more energy you consume the happier you will be?

Energy is necessary for every good and service we use, including food. In general, the lower a nation's per capita energy consumption, the lower its per capita Gross National Product (GNP) and the lower its material standard of living. Historically, over the last thousand years the standard of living and energy consumption appear to have increased very roughly in parallel.

On the other hand, countries with the same per capita GNP may use significantly different amounts of energy per capita. The Swedes, for example, use less energy per capita than we do. (Allowances must be made for each nation's climate and mix of industries.) Also, in our own country for the last ten years the ratio of energy consumption to GNP has been declining. Between 1973 and 1979, industrial energy consumption rose by 3.2% and output rose by 17%. Perhaps most telling, in the consumer or industrial area it is hard to find examples of ways of doing smarter instead of doing without.

In considering this question, students can benefit from looking at thier immediate situation and how they might improve the efficiency of their own use of energy.

Activities and Discussion Topics

Because this reading covers a number of separate topics the suggestions are arranged by paragraphs of the reading.

1. The Main Theme: "Some people seem to believe..."

Solicit opinions from the class. Is this true? In what ways? To what extent?

Refer to the activity sheet on appendix page 8-3 for another view of this question.

2. Recreation as an example: "Some ways of having fun..."

Here is an activity you can use to produce a chart on the chalkboard that compares the energy-intensiveness of different forms of recreation with the class' opinion of how much fun they are.

Make a chart on the chalkboard with one wide column and two narrow ones. Ask the students to give you the names of different forms of recreation, such as different sports, hobbies, things they do with their family, TV and movie watching, and so forth. List these in the wide column. Get as diverse a list as possible. Be non-judgmental; try to include anything any individual feels is fun.

In the second column, have the class rate each recreation according to how much fun they feel it is, on a scale from one to five, with five being the most fun. Try to put about one fifth of the total number into each category. If one category gets too many members, you can rank the items by comparing them two by two, shoving the least or most fun off into adjoining groups, depending on which have two few items.

In the third column, have the class estimate how energy-intensive each form of recreation is, from A to E, E being most energy-intensive.

Now compare the two lists. Are 5's mostly E's? Could you have a good time if you were restricted to A's?

3. Transportation Costs and Benefits: "A quarter of all the energy..."

What forms of transportation exist in your community?
What are people's need for transport? Can they be categorized?
How feasible is travel by bicycle in your community?

4. Trash as a Waste of Energy: "A lot of the energy..."

Ask students to make a list of the things they throw away in a day. Be sure to include the things others throw away on their behalf, such as mother discarding food wrappings, etc.

Can the discards be categorized?

Are there more economical alternatives?

As a homework assignment, students can be asked to discuss with a parent the last time an appliance or car was replaced in their home. What considerations lead the parent to decide to replace the old appliance (or to acquire a new one). What considerations lead to the choice of the model purchased. What role, if any, did energy have in this decision making. To avoid intruding on family privacy, the assignment can just be to get a slip from the parent saying, "I have talked with my son/daughter about how we decided to replace an appliance or car."

5. Survivals: "In the past, we made certain choices..."

Can you think of any buildings, objects, or ways of doing things that are no longer functional but can still be found in your community. (For example, in many communities horse watering troughs can still be found.) Do any of these survivals involve energy consumption?

What will be the effect of increasing energy costs on existing patterns in your community? Any kind of patterns.

Mini-Quiz

1. Name a form of recreation that you enjoy that uses a lot of energy.

2. Name a form of recreation that you enjoy that uses very little energy.

3. Name three ways of going downtown from where you live, ranking them in order of the amount of energy you think would be consumed in carrying you downtown.

4. Name something you threw away in the last week.

5. Name two costs and two benefits of owning a car. Then name two costs and two benefits of taking the bus.

6. Name two costs and two benefits to the community of your owning a car. Name two costs and two benefits to the community of your being able to take the bus.

7. Name one machine in your home that you know is not as efficient as others on the market. Describe the alternative.

Homework Assignments

1. Make a list of "free" things available in the community. This might include not only paper bags but also public services like schooling, and use of the library and roads. Determine how each of these things is really paid for. Determine the energy implications of each of the free things.

2. A proposal has been made that the government provide low-income owners of old gasguzzler cars with no-interest auto loans on condition that they buy new, small, fuel-efficient American-made cars and that the old car is scrapped. Prepare for and against arguments and debate the proposal in class.

ENERGY SAVING AT WORK (page 32)

Reading Level (by Fry count): 7th-8th grade (borderline)

Objectives

The student recognizes that reducing the amount of energy used reduces the cost of doing business.

The student identifies waste heat as an unused energy source.

The student realizes that some conservation measures require capital investment.

Vocabulary

substitution

Background Information

This topic becomes much more real if you can relate it to a local industry. It is sometimes possible to persuade some from a factory to speak to the class. (This can even be done by telephone.) Many industries have engineers who are specifically responsible for the plant's energy consumption.

Another alternative is to relate this topic to the school plant, or to challenges in the home or community that parallel those of industry. The same basic principles of energy-saving apply.

Costs

What effect have rising energy bills had on home use of energy? A lesson on one aspect of economic incentives for conservation is found on appendix page 7-15.

Activities and Discussion Topics

Changes in materials

1. A few years ago there was a brief controversy over which used more energy, permanent-press Dacron-cotton shirts or all-cotton shirts. Let's think of the entire system the use of either product implies. What would energy uses would be necessary to make and use each of the shirts. Make a two lists on the chalkboard.

Thrifty Habits

On appendix page 8-13 is an exercise requiring students to think carefully of ways energy might be saved by careful management.

2. Can you think of other products where materials substitution has taken place, perhaps in an effort to save manufacturing costs? (An typical example is thread spools, which are now plastic instead of wood.) How could one estimate whether energy had been saved?

Interruptible Power

3. Are some uses of energy in a community more important than others? Do you think people could agree on the last use they would want cut off? What would it be?

4. Suppose you had to give up the use of some appliances in your home whenever energy was in short supply. Which appliances would you feel must be kept on? Which wouldn't matter? For which would cutting them off create a minor inconvenience? (Cutting off the freezer is a disaster, a clock is a minor inconvenience, a washing machinewell, the laundry can wait. There is a similiar spread in industrial processes.)

Can you think of any industrial processes where a temporary shutdown is very damaging? (an example to get started: film processing)

Using Waste Heat

5. What are some sources of waste heat in your home? How could they be utilized? (For example, in the winter, letting the hot water cool to room temperature after a bath before draining it saves a large number of furnace Btu's.)

Whole New Processes; Capital Investment

6. At home, if you had money to spend could you reduce your energy consumption. By doing what?

How do increasing costs motivate people to save energy?

Mini-Quiz

[Sorry, we couldn't think of any way of evaluating this topic using recall questions.]

1. Why would a utility offer lower prices to a firm that agrees its power can be cut off at any time?

2. Give one reason why, in the past, overseas companies were more interested than American firms were in finding ways to do things with less energy. [Energy was cheaper here.]

3. Suppose there are two firms, Firm A and Firm B, that make similar products that sell for similiar prices. Firm A uses twice as much energy as B per product made. Other things being equal, for which firm would you rather work? Why? [Firm B, if one argues that their costs are less and so your job is likely to be more secure. Or, one might answer Firm A, arguing that if they can sell the product for the same price now, and there is so much room for improvement in energy consumption, when they make the energy changes they will be able to undercut B's price.]

APPENDIX

This guide is part of a larger program which provides a sequence of lesson plans, almost all of which include activity sheets, worksheets, or readings, for an interdisciplinary course in energy at the junior high school level. No charge is made to schools for the materials; costs are borne by corporations in the state who are concerned about the next generation's understanding of energy.

The approach taken in the materials is:

quantitative (using SI units, with the exception of the calorie and Btu)

hands-on, emphasizing activities and investigations, and in the social studies, the use of primary source materials. To make it possible for individual students to use the activities and investigations, activity sheets and readings are as self-contained as possible, providing complete instructions and questions.

comprehensive The course follows the same sequence of ideas that is presented in the booklet you are using, though with some additions and a great deal more detail.

Because of space limitations in this guide, it has only been possible to give selections from the units, of which there are eight in all:

1. Energy Fundamentals
    - Energy has different forms
    - Energy can be converted from one form to another
    - Energy can be measured
        - Heat
        - Work
        - Electricity
        - Reading utility meters
        - Reading utility bills
    - First-Law Efficiency
    - Loss of available work with conversions
2. Energy From the Sun
    - Water cycle
    - Wind cycle
    - Photosynthesis
        - detecting chlorophyll, starch
        - measuring energy in food; calorimeter
    - Respiration
        - detecting seed respiration
        - detecting carbon dioxide before & after exercise
    - Food chains
    - U.S. Food system
    - Origin of fossil fuels

3. Fossil Fuels: History and Technology
    - Value of fuel illustrated historically
        - preparing raw materials: smelting
        - fuel as a source of work
    - Comparing wood and coal, 1300's
    - Coal and the Industrial Revolution
    - Drake's Well
    - Petroleum geology
    - Petroleum refining
    - Rise of the internal combustion engine
    - Comparing coal and gas, United States 1900
    - Pipelines
    - LNG
    - Cleaning up coal

4. Energy from Nuclear Fission
    - Atoms and elements,
    - Radioactivity
    - Transmutation
    - Isotopes and half-life
    - Fission and chain reactions
    - The lightwater reactor
    - Breeding
    - The uranium fuel cycle
    - Radiation and life
    - Risks
    - Comparing the uranium and coal fuel cycles

5. Renewable Energy Sources
    - Why renewables
    - Absorbing sunlight
    - Flat plate collectors
    - Water heater payback
    - Movement of the sun
    - Passive solar
    - Concentrating collectors: parabolas and rotisseries
    - Biomass: methane, alcohol
    - Directed student research reports

6. Energy in the United States
    - Energy in daily life through primary source materials, from outstanding authors and historical figures from 1605 to 1950
    - Review of energy transitions
    - Present sources and uses nationally
    - Present sources and uses household

7. Economics and Decision Making
    - What's Happening?!
    - Supply and demand
    - Comparing consumer alternatives
    - Present Value
    - Life-cycle costing

8. Conservation
- What Can Conservation Do?
- Conduction of heat in the home
- Infiltration in the home
- Water heating
- Habits
- Automobile
  - design features
  - driving habits
  - maintenence
- Conservation and the Quality of Life

Unit One
Energy Fundamentals

Energy Transformations

Worksheet

Energy can be converted from one form to another. We often need to do this when we use energy.

In each of the empty boxes below, write a way of converting energy from the form named on the left side to the form named at the top. An example is done for you. Some of the answers are easy; some are hard. Do as many as you can.

To This Form of Energy

How to Convert This Form of Energy

	heat	motion	light	electricity	chemical	nuclear
heat	▨					
motion		▨				
light			▨			
electricity			light bulb	▨		
chemical energy					▨	
nuclear energy						▨

Making a Light Bulb

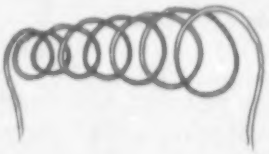
The incandescent light bulb has been in use since Thomas Edison introduced the first practical version in 1879.

Try to make a light bulb yourself. You will need:

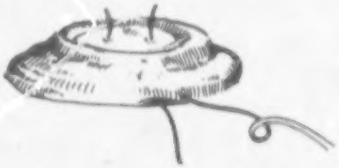
☐ wire for the filament
☐ wire for the connections
☐ a source of electricity, such as a dry cell
☐ a clear jar or cup
☐ modeling clay

Do you have all the things you need?

1. The filament: Take a piece of iron picture-hanging wire about 10 cm long. Unbraid it until you get a single strand of wire (share the other strands with your classmates). Wrap the wire around a pencil, pen, or other round object to form a coiled filament. Leave 2 cm of straight wire at each end. It should look like this:

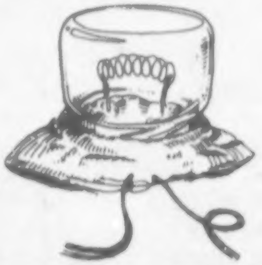


2. The base: Flatten a piece of modeling clay big enough to cover the mouth of your jar. Stick the two bare ends of your connecting wires through the clay. The wires should be just as far apart as the filament is long. It should look like this:



3. Finishing the bulb: Attach the filament to the wires by wrapping the filament wires around the connecting wires. Put the globe over the filament and press it to the base. Check to be sure that the filament wire is still touching the connecting wire, and the connecting wires don't touch each other anyplace.

4. Light up!



Observations

1. Which part of the light bulb gives out light? ______________________

2. Is there evidence of any other form of energy besides light coming from the light bulb?

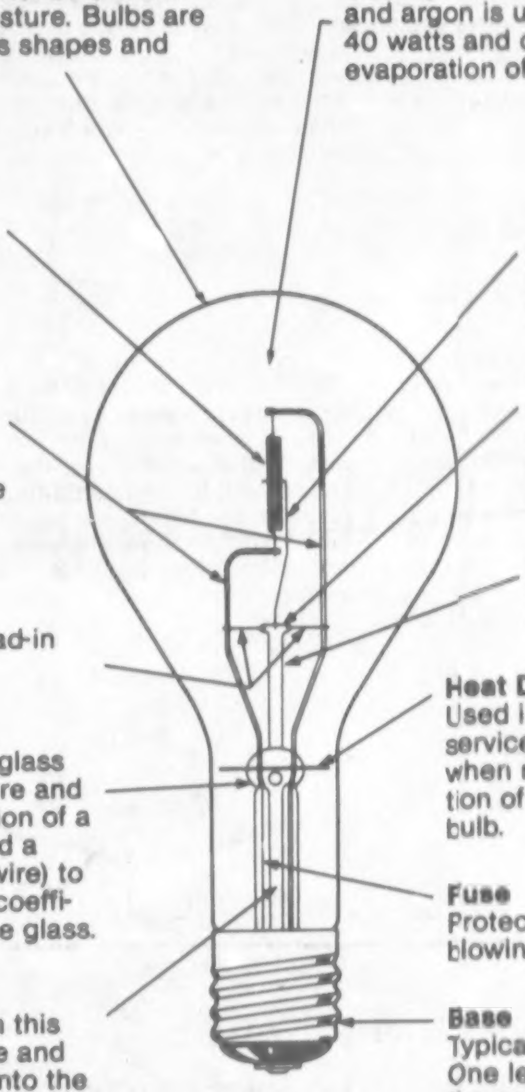
____

____

3. Trace the energy flow from a dry cell to a flashlight bulb. Four forms of energy should be listed.

______________ → ______________ → ____________ + ____________

4. About how many years has the incandescent light bulb been in use? ________



Bulb
Soft glass is generally used. Hard glass is used for some lamps to withstand higher bulb temperatures and for added protection against bulb breakage due to moisture. Bulbs are made in various shapes and finishes.

Gas
Usually a mixture of nitrogen and argon is used in lamps 40 watts and over to retard evaporation of the filament.

Filament
The filament material generally used is tungsten. The filament may be a straight wire, a coil, or a coiled coil.

Lead-in Wires
Made of copper from base to stem press and nickel-plated copper or nickel from stem press to filament, they carry the current to and from the filament.

Tie Wires
Molybdenum support lead-in wires.

Stem Press
The lead-in wires in the glass have an air-tight seal here and are made of a combination of a nickel-iron alloy core and a copper sleeve (Dumet wire) to assure about the same coefficient of expansion as the glass.

Exhaust Tube
Air is exhausted through this tube during manufacture and inert gases introduced into the bulb. The tube, which originally projects beyond the bulb, is then sealed off short enough to be capped by the base.

Support Wires
Molybdenum wires support the filament.

Button
Glass is heated during manufacture, and support and tie wires placed in it.

Button Rod
Glass rod supports button.

Heat Deflector
Used in higher wattage general service lamps and other types when needed, to reduce circulation of hot gases into neck of bulb.

Fuse
Protects the lamp and circuit by blowing if the filament arcs.

Base
Typical screw base is shown. One lead-in wire is soldered to the center contact and the other soldered or welded to the upper rim of the base shell. Made of brass or aluminum.

Typical Incandescent Lamp

Courtesy of GTE Sylvania

Changing Light to Motion

Objectives

This lesson contributes to students' understanding of the following concep[illegible]

Light heats objects which absorb it.

Light energy can be converted to motion.

Some light is not visible.

Heat is not a form of light.

Format of the Lesson

Introduction of radiometer

The more light, the faster it spins

How the radiometer works

Different forms of light

Comparison of infrared radiation with heat

Materials Needed

Crookes radiometer available from novelty stores, as well as scientific supply houses. (Edmund Scientific, Catalog #60,082, $5.95.) Providing each group with its own radiometer is helpful though expensive, since it gives individual students a chance to try the device for themselves.

source of visible and infrared light sunlight can be used for the visible light, but a more manipulable source is helpful. One can be made by using a lamp socket on the end of a cord. Some "trouble lights" are suitable, or make one by plugging a prong-to-socket adapter (.75¢) into an extension cord. A small reflector flood makes a good light. Convert it to infrared by adding a filter such as one from Edmund Scientific (Catalog #60,033), $4.95. Or use an ordinary flashlight; an infrared filter to fit a flashlight is also available from Edmund (Catalog #42,143) for $2.

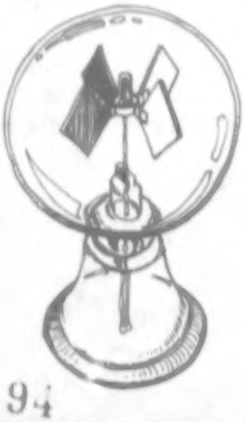
Introducing the Radiometer

Set up the radiometer in a window (or direct a visible light source on it, though the window is better since, if students are not already familiar with the radiometer, using the window avoids "giving away" the connection with light). Ask students to describe what's happening. What kind of energy can be detected inside the glass bulb? (ANS: Motion, or mechanical energy.)

Where does this energy come from? How can we tell?

Compare the intensity of the light falling on the radiometer with its rate of rotation. Vary the light by shading the radiometer or placing it varying distances from the window or light source. Quantify the energy of motion by counting the number of rotations in 30 seconds. If several radiometers are available, ask groups of students to investigate different intensities.

Ask where the energy of the turning vanes comes from. Students will answer that it must be from light, since the vanes don't turn in the absence of light, and the more light there is, the faster the vanes turn.



How the Radiometer Works

What can be observed about the vanes? (ANS: They are black on one side; white on the other.)

Which absorbs more light, black or white? (ANS: Black.)

Which side of the vane is hotter? (ANS: The black side.)

Explain that there is air inside the radiometer (but at less than atmospheric pressure). The unequal heating of the vanes leads to a very small difference in air pressure at the surface of the vanes, which makes them rotate.

Please note that the explanation given by the manufacturer on the radiometer packaging (that molecules striking the black side bounce off with more energy, giving the vane a greater kick) is at best oversimplified and should not be used. The rotation of the radiometer is due to a phenomenon called thermal transpiration, in which gas creeps toward the hotter parts of the vane causing locally increased air pressure.

Refer students who want further information to the article "Radiometer" in the **Encyclopedia Britannica.**

Light Pressure—Optional Topic

With advanced students, you may wish to discuss the following additional information:

If all the gas could be removed from the bulb, and the bearing had even less friction, the vanes would turn in the opposite direction!

This would occur because of "light pressure." The photons of light are more strongly absorbed by the black side than the white side. In the space in front of the white side, the photons reflected from the white side are added to those streaming in, so there is a greater "density" of photons in front of the white side than in front of the black side. The greater pressure causes the radiometer to turn. In fact, however, it is not practical to demonstrate light pressure with radiometers of this design.

The effects of light pressure can be seen in the motion of comets' tails, which swing to point away from the sun. Light pressure is also of crucial importance in what happens inside stars.

A Light We Cannot See

Provide two artificial light sources, one of visible light and the other largely infrared. You can do this by putting a filter in front of a flood lamp, or by using a commercial heat lamp. Ask the students which light is brighter; they will choose the visible light.

As our earlier investigations with the radiometer showed, we can vary light intensity by adjusting distance. If you can darken the room, shine the two sources alternately on a piece of paper, moving the visible source farther and farther away from the paper, until an approximate visual balance is reached. Note the distances.

Now compare the strengths of the two light sources by shining them on the radiometer from the distances established in the visual comparison. The infrared source will cause the faster rotation. Why?

Point out that we cannot see all kinds of light. Visible light is only one part of the spectrum of radiation. All incandescent light bulbs emit a mixture of visible radiation and infrared radiation, but one of the bulbs we are using has been made to emit mostly infrared and little visible light. The radiometer is sensitive only to how much heat is produced by the absorption of the light, not to whether it is blue, red, yellow, or infrared light.

As it happens, infrared light is very strongly absorbed by objects, more so than visible light. We use infrared to heat everything from rooms to freshly painted automobiles. Sometimes it is called "radiant heat." But notice that it is really radiation, not heat. Only matter can have heat; infrared radiation can and does travel through a vacuum, just like the other radiation from the sun.

Projects for Independent Investigation

1. Some students may be interested in building other machines that convert light to motion as Crookes' radiometer does, using heat as an intermediary form.

NASA designed a solar motor that consists of a long metal tube painted black and pivoted on the ends. Sunlight can only hit one side at a time, so the lit side expands more than the shaded side, warping the tube. The warped tube is unbalanced; the bulge falls — bringing the cool side up. Now it expands, the bottom shrinks, and so on.

Clear directions for building such a motor are given on pages 50-54 of **Exploring Solar Energy**, by Thomas H. Metos and Gary G. Bitter (New York: Julian Messner, 1978). It is a fairly complicated project.

A second type of "solar engine" uses rubber bands or plastic strips, which contract when they are heated. Directions for building such an engine are given on pages 126-128 of the February, 1980, issue of **Popular Science** ("Build a Sun Tracker and a Solar Engine with Solar Muscle"). A different design, for a rubber band engine, can be found in the "Amateur Scientist" columns of the May, 1956, and April, 1971, issues of **Scientific American**. These are not as difficult to construct as the NASA motor.

2. What would happen if a spinning radiometer was placed in an environment that was colder than the vanes? Such an environment can be created. Choose a tin can higher than the radiometer and only a little bit larger in diameter, which the radiometer will fit into. Paint the inside of the can flat black. Glue it into the middle of a larger tin can. Pack the space between the two cans with ice and salt. After the cans have cooled, get the radiometer spinning as fast as possible in a strong beam of light, then quickly place it in the can. You can observe what happens by looking down on the radiometer from above. What does happen? Why?

3. A prism will split light into its various colors. Even though you can't see it, the prism also splits out the infrared. Can you devise a way of measuring the heat energy in the various bands of light, including the infrared? (Hint and caution: not all blacks are equal.)

Changing Motion to Electricity; Changing Electricity to Motion

Objectives

This lesson contributes to students' understanding of the following concepts:

An electric motor converts electrical energy to mechanical energy.

The electric generator converts mechanical energy to electrical energy.

Magnetism is used in accomplishing this conversion.

Format of the Lesson

This lesson relies on a "gee-whiz" effect. We demonstrate a phenomenon that engages student interest, observe it closely while altering various variables, and then discuss what might be happening. Several sets of the apparatus needed for the demonstration can be constructed in class, if you have that many bar magnets; or you may wish to have an able student construct a set for you in advance as an individual project. It isn't hard to do; the picture on the activity sheet is enough explanation. The activity sheet also provides some guidance for a period of student puzzling over how the set works. It is important to provide "free time" for this puzzling. Some optional experiments are provided at the end of the lesson for classes who wish to examine in more detail how the set works; i.e., learn more about the relation between electricity and magnetism.

Materials Needed

(For each set of two swings)

bar magnets two. Available through scientific supply catalogs, around $7 a pair (Fisher 543034).

wire #28 magnet wire (100 feet). Available through scientific supply catalogs or electronic supply houses, about $8 a pound (616 meters).

milk cartons two empty 1/2 gallon cartons. Save from kitchen.

cardboard two pieces about 3" x 12" each.

masking tape

cylinder, to form coils. Can be a flashlight, cardboard tube, or olive bottle.

knife

The Apparatus

Please look at the picture on the activity sheet.

The electric motor-generator swing consists of two identical coils of wire, each suspended so that a bar magnet passes through the hole in the coil without touching the coil. The two coils are connected to each other. When mechanical energy (a moving hand) is used to set one coil into pendulum-like motion, the other coil starts to move, too!

The swing demonstrates the fundamental principles of both the electric motor and the electric generator, and shows why they have basically the same parts. An additional benefit is that introducing motors and generators this way doesn't require students to understand commutator switching, which can be a roadblock.

Basically, the apparatus works as follows: Whenever a wire moves through a magnetic field, the magnetic field pushes some electrons down the wire. That's what's happening in the coil we set in motion by hand. (Call it coil A.) The resulting electrical current flows through the wire to coil B. Whenever an electric current flows through a wire, it sets up a magnetic field around the wire. So, there is a magnetic field around coil B, with a north and south pole. This magnetic field interacts with the magnetic field of the bar magnet, attracting and repelling. As coil A changes the direction of its motion in respect to its magnet, the direction of the current in the wire changes. That reverses the magnetic poles of coil B, causing a change in the direction of its motion. So the two coil-pendulums swing together.

Sub-Investigations

Does moving the coil near the magnet generate electricity?

Connect the lead wires to a galvanometer and see. Also investigate the relationship between direction of motion and direction of current.

Is the coil of wire a magnet when electricty is flowing through it?

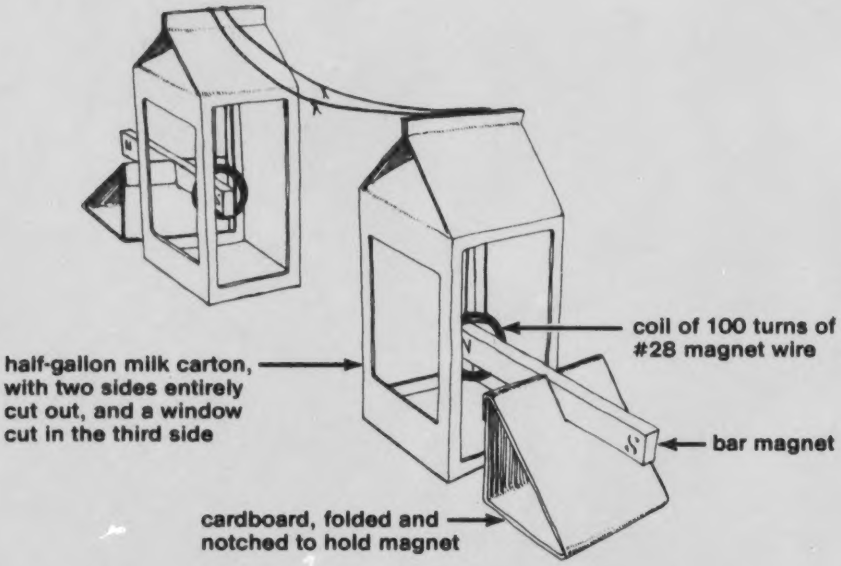
Energize the coil with a 1-1/2 volt battery. Hold the coil in one hand and a permanent magnet in the other. Can you feel any force of attraction or repulsion? Does it go away when the battery is disconnected?

Or, fit the coil into a white card, perpendicular to the coil. Sprinkle with iron filings.

The Mysterious Swing

Construct the swing set from the materials listed below. Then do the activities.

Materials and Construction


coil of 100 turns of #28 magnet wire
half-gallon milk carton, with two sides entirely cut out, and a window cut in the third side
bar magnet
N
S
cardboard, folded and notched to hold magnet

Assembly of Materials

Arrange the apparatus according to the above diagram.

1. Cut two sides of the two empty 1/2-gallon milk cartons. Cut a window in one or both of the remaining sides.

2. Make two coils by wrapping about 100 turns of wire around the end of a flashlight or other cylinder about 4 cm in diameter. Do not change direction while wrapping. Leave two tail ends of wire, each about 50 cm long, and tape the coil together in a few spots.

3. Force the two wires up through the top of the milk carton so the coil hangs as a swing about two inches from the floor of the carton. Bend the wires over slightly when the swing is in position and staple the top of the milk carton together. When you are finished the two milk cartons should look alike.

4. Strip the insulation off the ends of the wires. Twist together as shown in the diagram.

5. Fold each of the two pieces of cardboard into a triangle and cut a notch to support the bar magnet.

6. Position the bar magnets so that the north pole is centered through one coil and the south pole is centered through the other coil (see diagram).

Observations

1. What happens to the two coils when you give one coil a push?
2. What happens if you reverse the connections between the coils?
3. What happens if you reverse the poles of one of the bar magnets?
4. Trace the flow of energy through the apparatus.

Electric Motor Inventory

Use the worksheet below to take inventory of the electric motors in use in your home. For each one you check, also write down how you might do the same job without the use of an electric motor.

Appliances with Electric Motors	Other Ways of Doing the Job
☐ garbage disposal	
☐ mixer	
☐ blender	
☐ ice cream maker	
☐ fan	
☐ record player	
☐ tape player	
☐ garage door opener	
☐ electric drill	
☐ electric saw	
☐ hair dryer	
☐ refrigerator	
☐ air conditioner	
☐ furnace (blower, oil pump)	
☐ toothbrush	
☐ clock	
☐ sewing machine	
☐ any others you can think of	

Heat and Its Measurement

Objectives

This lesson contributes to the students' understanding of the following concepts:

Heat is a form of motion, the random motion of molecules.

Temperature describes how fast the molecules are moving.

To measure a quantity of heat, we must measure mass and a temperature difference.

Format of the Lesson

Discussion of difference between temperature and heat

Kinetic theory of heat

Defining the calorie

Activity measuring temperature

How do we measure heat?

Activity

Materials Needed

thermometers Celsius scale, one for every two students.

jars or Thermos® bottles, one per group, though they will circulate between groups.

candles hot plates, or laboratory burners.

worksheet one per student.

Pyrex® beakers tin cans, or other containers, one per group

microscopes, microscope slide, cover glass, and either india ink or gamboge (optional) one per group, to observe Brownian movement. Gamboge is a yellow watercolor available at art supply stores; a small tube is about $3.50 but you can probably get the tiny speck needed from the art instructor.

Discussing Temperature and Heat

What do we mean when we say it's a hot day? How do we know it's hot? (ANS: The temperature is high.)

Suppose I'm hungry and I have a pizza in the freezer. I take it out. Will its temperature be high or low? (ANS: Low.)

I put it in the oven and pretty soon the cheese is all melted and gooey and the crust is crisp and the tomato sauce is bubbling. Is its temperature high or low? (ANS: High.)

Tell me, in terms of energy, what happened between the low-temperature pizza and the high-temperature pizza. (ANS: Heat energy was added to the pizza.)

There is energy in the pizza, right? In my oven, I converted some chemical energy in natural gas to heat energy, and that raised the temperature of the pizza.

What is the difference between heat, the form of energy, and temperature?

Let's look at the hot pizza again. There's a certain amount of that energy in the pizza, right? Suppose I cut the pizza in half. How much of the energy in the uncut pizza will each half have? (ANS: Half.)

OK, suppose I cut the pizza into 16 slices. How much of the energy in the original hot pizza will be in each slice? (ANS: One-sixteenth.)

What about the temperature of the slices of pizza? Will they be one-sixteenth the temperature of the hot pizza? (ANS: No, they'll be the same temperature, cooling aside.)

Here's a trick question. I have two full bottles of warm water, a bottle that holds a liter and another bottle that holds a half liter. The water is the same temperature in both bottles. In which bottle is there more energy — or are they both the same? (ANS: More energy in the big bottle.)

Kinetic Theory of Heat

Heat energy is really a kind of motion energy, but it's the random motion of molecules. When you walk down the street, all your molecules are moving in more or less the same direction. That's what we usually think of as motion. When you get sick and you're lying in bed with a temperature of a hundred and one, your molecules are jiggling around a little faster than they would be if your temperature were ninety-eight point six. Your molecules are moving, just as they always are, but you're not moving. It's every molecule for itself, moving willy-nilly every which way. In a solid (and liquid) body like you, the molecules are more or less held in one place by other molecules.

Temperature is a description of the speed with which the molecules are jiggling. The higher the temperature of an object, the faster its molecules are jiggling.

But to measure the amount of heat energy in something, we need to know not only the average speed, but also the mass of the moving molecules. The greater the mass in motion, the more energy. Doesn't it make sense that there's more energy in a big semi-trailer traveling fifty-five miles per hour than in a motorbike doing fifty-five, even though they're moving at the same speed?

Brownian Movement

If you have the necessary microscopes, a visual demonstration of the kinetic nature of heat makes a lasting impression on students. Put a tiny speck of india ink or gamboge into a drop of water on a slide, cover with a cover glass and view under high power. The particles of ink or gamboge dance because they are so small that there are not enough collisions with moving water molecules to average out to no motion. It is like subtracting heads from tails when flipping coins. If you flip millions of coins, the sum will be very near zero. If you flip only two, it may be +2 or −2. It is the plus and minus two's we see in the dance of the small particles.

Defining the Calorie

To measure anything, you first have to define a unit of measurement. The unit we will use to measure heat is called the calorie. Our definition will have to include two things:

1) the mass which is heated

2) the average speed of the molecules in the mass or, in other words, the temperture

The calorie belongs to the metric system,* so the units used are metric. Mass is measured in grams, and temperature is measured using the Celsius scale.

We have heat only when there is something that is being heated. It turns out. that some substances are harder to heat than others; that is, adding a given amount of heat doesn't produce the same rise of temperature in all substances. For example, if I put some cooking oil in one pot and some water in another, identical pot, and put them on identical burners on the same stove, the temperature of the oil would go up faster than the temperature of the water. It is harder to raise the temperature of water than just about anything else. Also, water is one of the commonest substances, and we do a lot of water heating in cooking, industry, and so forth. So we'll use water for our definition.

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*Actually, the calorie is not the unit of energy in the International System of Units; the joule is. Unfortunately for pedagogic purposes, there is no convenient way middle school students can measure heat in joules directly. Calories can be measured simply, so we use them.

Here is the definition of a calorie: the amount of (heat) energy needed to raise the temperature of one gram of water one degree Celsius (at 15°C).

We specify the 15° Celsius because the amount of heat needed to raise the temperature of one gram of water from 15° to 16° is not exactly the same as the amount needed to raise it from, say, 80° to 81°. However, the difference is so small we'll ignore it in our own investigations, because we can't measure that precisely anyway.

We're going to do an activity to measure heat, but first let's practice measuring temperature.

Divide the class into groups and distribute the thermometers.

Confirming Students' Skill in Thermometer Reading

The initial activity provides an opportunity for you to satisfy yourself that all students understand how to read a thermometer. Since most students are able to do this, working in pairs can provide those who do not have the skill with a tutor.

Ask the students to number a sheet from one to however many groups you will have. In advance, prepare that number of jars, or preferably Thermos bottles, of water at various temperatures. One can contain ice water, one water that is as hot as the tap will provide, and others at temperatures in between. It is perfectly all right to have some jars with identical temperatures. Label the jars with numbers, one through however many groups you have.

Give each group a jar. Ask the students to measure the temperature of the water in their jar and enter the measurement on their paper next to the number of the jar. Then trade jars with another group.

While this activity is going on, walk around the room and provide individual attention where it is needed.

Measuring Heat

When you are satisfied that all students can read a thermometer, terminate this activity and pass out the worksheets. Set up a station where students can safely heat their containers. This may be an electric hot plate, a can of Sterno, or a laboratory burner. Supervise this station to remind students that heating the water to boiling is NOT the object. In some classes, you will already have run out of time and will have to carry over the lesson to the next meeting of the class.

Measuring Heat

In this investigation, you will learn how to measure heat. To do the investigation, you need:

☐ a thermometer marked with the Celsius scale

☐ a graduated cylinder

☐ a Pyrex® beaker, metal pan, or tin can

☐ water

☐ a source of heat, such as laboratory burner. You can share a heat source with others.

Do you have everything you need?

You are required to memorize the definition of a calorie: A calorie is the amount of heat needed to raise the temperature of one gram of water one degree Celsius. Remember, a mass of one gram of water takes up a volume of one milliliter.

Procedure

Step One: Measure out some water, using the graduated cylinder, and put it in your container. Record the volume of water ____________ milliliters

Step Two: Remember, one milliliter of water has a mass of one gram. What is the mass of the water in your container?

____________ grams

Step Three: Use your thermometer to measure the beginning temperature of the water.

____________ degrees Celsius

Step Four: Take your container to the heat source and add some heat to it. Add enough heat to be noticeable. Don't get the water so hot it could burn you.

Step Five: Measure the temperature of the water now.

____________ degrees Celsius

Step Six: Now you are ready to calculate how many calories of heat were added to your container.

(temperature difference in degrees Celsius) X (mass of water in grams) = calories

end temperature = ____________ °C

beginning temperature = – ____________ °C

temperature difference= ____________ °C

mass of water in grams = X ____________ grams

____________ calories

Heat Flows

Objectives

This lesson contributes to students' understanding of the following concepts:

Energy cannot be created or destroyed.

Energy can be measured.

Heat flows from hotter areas to colder areas.

The universe tends to become the same temperature throughout.

The greater the difference in temperature between two objects, the faster the flow of heat between them.

Format of the Lesson

Discuss whether heat is destroyed when objects cool

Explain investigation

Conduct investigation

Discuss results

Discuss implications for energy flow in universe

Investigate rate of heat flow

Discuss results

Materials Needed

container with a lid, such as a half-gallon plastic container. The less conductive, the better, so plastic is better than metal. One per group.

tin can that can be placed inside above container.

masking tape one roll.

old newspapers corrugated cardboard, or other insulating materials.

thermometer graduated in degrees Celsius.

water at room temperature. If it is warmer than room temperature, it will lose heat to the surrounding air during the investigation; and if it is colder than room temperature, it will gain heat from the air. This additional flow can confuse the students.

graduated cylinders 100 or 250 mL. One per group. You can substitute bottles that you have calibrated yourself.

gallon jugs to store water in advance so that it will be at room temperature. Four jugs are plenty.

hot plate or other heat source.

large beaker or pan with a pouring lip, for heating water which you will dispense to the students.

graduated cylinder for measuring hot water dispensed to students. One.

clock with sweep second hand, wristwatches, or stopwatch.

activity sheet **Tracking the Elusive Calorie**, one per student.

worksheet **Calculation of Heat Flow**, one per student.

activity sheet **Does the Size of the Temperature Difference Affect the Rate of Heat Flow?** one per student.

worksheet **Calculation of Rate of Heat Flow**, one per student.

Preliminary Discussion

Ask the class, if we had a hot electric iron here in the room, and we turned it off, what would happen to the iron? (ANS: It would grow colder.) What happened to the energy in the iron? Students may suggest a variety of explanations, or they may all recognize that the heat flowed into the room air. In either case, suggest that this is a hypothesis: that when an object cools, no energy is destroyed, but simply lost as heat transferred to some other object.

We can test this hypothesis by measuring the heat flowing out of an object and also the heat flowing into the object's surroundings. Will the amount of heat the object has lost be the same as the amount of heat gained by the surroundings?

Review how we measured heat: measure the mass and the change in temperature.

Pass out the worksheets and the materials.

Handling the Hot Water

In this investigation, students need a tin can three-quarters full of very hot water. You will provide this. One way is by walking around the classroom with a pitcher of hot water, measuring it with a graduated cylinder, and pouring it into the tin cans at the tables. An alternate procedure is to dispense water to the students at some central station. In the latter case, have students make hot pads from layers of newspaper to make it easier to carry the hot cans back to their tables.

After the Investigation

On chalkboard, make two headings:

HEAT LOST BY WATER IN TIN CAN

HEAT GAINED BY WATER IN CONTAINER

Ask the groups for their results and enter them in the columns. If all the students used identical containers and tin cans, find an average for the class.

Does the heat lost by the hot water match the heat gained by the room temperature? How big might our measurement errors have been? What are some other factors that might have affected our results?

We can conclude that heat does flow from hot objects to cooler ones. Does heat ever flow from cold objects to hot ones?

The "Heat Death" of the Universe

If you have a sealed room in which there are some hot objects, like an iron, and some cold objects, like a glass of ice water, what will happen as time passes? (ANS: Everything in the room will become the same temperature. The cold things will warm up and the hot things will cool off.)

What about in the whole universe? There are hot things and cold things, obviously. What happens as time passes? (ANS: Everything tends to become the same temperature.) The whole universe keeps warming up as other forms of energy are converted to heat and the heat spreads to cooler parts of the universe. It may be that, in billions of billions of years, long after the sun has gone out, the universe will be all the same temperature. This is certainly the tendency of heat flows.

Yet we see lots of exceptions. Consider this idea in relation to our planet, Earth. Is everything on earth the same temperature? What seems hotter than average? Is an energy input needed to make such things hotter than most things? Discuss some specific examples, like the polar caps or the warmth of living mammals or volcanoes. Point out that, in each case, we can identify an input of energy. A constant supply of energy is always needed to prevent everything from becoming the same temperature.

In advanced classes, you may wish to go on to discuss the concept of entropy. See the references in **Additional Resources**, at the end of this unit, for help in doing this.

By this time you have probably reached the end of the period. This is a convenient point at which to break.

Investigating the Rate Of Heat Flow

Review the previous investigation. In doing so, it is useful to introduce two new words: *source*, meaning the matter from which heat is flowing; and *sink*, meaning the matter to which the heat is flowing. In our investigation, the source was the tin can of hot water, and the sink was the room-temperature water in the container.

Point out to the class that in the investigation we also measured a rate, namely, calories per ten minutes. On what factors does this rate depend? For example, we might guess that the hotter the source is, the faster the rate of heat flow to the sink will be. Let's do another investigation to determine how differences in temperature affect the rate of heat flow.

Pass out the worksheet, **Does the Size of a Temperature Difference Affect the Rate of Heat Flow?** and the necessary materials, which are identical to those used in the previous investigation.

Post-Activity Discussion

On the chalkboard, make a graph comparing difference in temperature (in degrees Celsius) with rate of heat flow (in calories per minute). What, if any, conclusions can we reach?

Projects for Independent Investigation

1. In a refrigerator, heat is transferred from the cold interior of the refrigerator to the warm kitchen. In other words, there is a heat flow from cold to warm! How can this be possible? Do some research on how refrigerators work and report to the class.
2. If you turn down the thermostat on your water heater, you will save gas (or electricity). But how can this be? You will still be taking baths or showers at the same temperature, using the same amount of water. In other words, there will be just as many Btu's in the bathtub as before. To get those Btu's, you will have to mix a greater proportion of hot water to cold water at the faucet because the hot water is not as hot as it used to be. You're using cooler hot water but more of it. This being so (and it is) how can it be possible that less fuel is being used (which is also true)?
3. Imagine a woman who takes her coffee as hot as possible, and with cream. (The cream is cold.) She is in a restaurant. The waiter pours the coffee, but the woman doesn't want to drink it until ten minutes from now, when her dessert comes. She turns and asks you: "In order for my coffee to be as hot as possible ten minutes from now, should I put the cream in now, or wait ten minutes and put it in when I'm ready to drink the coffee?" Test your answer experimentally.

Tracking the Elusive Calorie

Is heat destroyed when objects cool off? Let's find out.

To do this investigation, you need:

☐ a small tin can

☐ a thermometer

☐ some old newspaper or other insulation

☐ masking tape

☐ a container with a lid

☐ some water

☐ a graduated cylinder

Do you have everything you need?

Procedure

Before beginning, read all the steps.

Step One: Insulate your container as well as you can. Try taping layers of newspaper around it loosely. Put some corrugated cardboard under it.

Step Two: Measure some water and put it into the container until the depth of the water in the container is about half the height of your tin can. Record the volume of water on the worksheet.

Step Three: Measure the temperature of the water in the container. It should be about room temperature. Record the measurement on the worksheet.

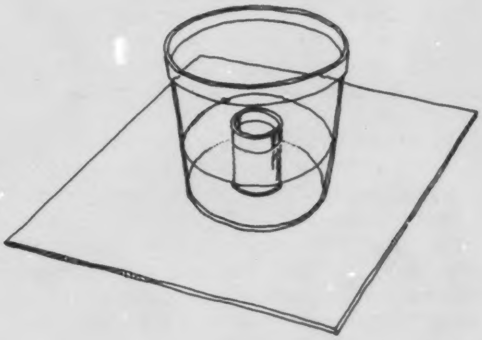
Step Four: Take your tin can to your teacher. The teacher will fill it with a measured quantity of hot water. Record the volume. Carefully take the can back to your table.

Step Five: Quickly measure the temperature of the hot water. Record your measurement below.

Step Six: Put the tin can full of water into the container of room-temperature water. Put the lid back on the container.

Step Seven: Let about ten minutes go by. Then take the lid off the container and quickly measure the temperatures of the water in the tin can and the water in the container. Stir the water with the thermometer before reading its temperature. Measure the temperature of the water in the tin can first. Record your measurements.

Step Eight: Do the calculations below.



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Calculation of Heat Flow

1. Heat Lost by Hot Water in Tin Can

beginning temperature = ____________ °C

end temperature = – ____________ °C

change in temperature = ____________ °C

volume of water = ____________ milliliters ≅ x ____________ grams

heat lost by hot water = ____________ calories

2. Heat Gained by Room-Temperature Water

end temperature = ____________ °C

beginning temperature = – ____________ °C

change in temperature = ____________ °C

volume of water = ____________ milliliters ≅ x ____________ grams

heat gained by room-temperature water = ____________ calories

Does the Size of a Temperature Difference Affect the Rate of Heat Flow?

We can describe the rate of a flow of heat in calories per minute. Suppose we have two setups in which heat is flowing from a hot source to a cold sink. The setups are identical except that in one the difference between the temperatures of the source and sink is very great; in the other, they are almost the same temperature. Do you think the heat will flow at the same rate in both setups? Or do you think the rate of heat flow will differ?

In this activity, you will make one setup, and other groups will make other setups identical to yours except for the temperature of the hot water. That way we can obtain measurements of the rate of heat flow at various differences in the temperatures of the source and sink.

(We will always start with room-temperature water in the container, since that minimizes heat flow between the container and the surrounding air.)

To do this investigation, you need:

☐ a small tin can

☐ a thermometer

☐ some old newspapers or other insulation

☐ masking tape

☐ a container with a lid

☐ some water

☐ a graduated cylinder

☐ clock or watch with a sweep second hand

Do you have everything you need?

Procedure

Before beginning, read all the steps.

Step One: Insulate your container as well as you can. Try taping newspaper around it loosely. Put some corrugated cardboard under it.

Step Two: Measure some water and put it into the container until the depth of the water in the container is about half the height of your tin can. Record the volume of water on the worksheet.

Step Three: Measure the temperature of the water in the container. It should be about room temperature. Record the measurement on the worksheet.

Step Four: Take your tin can to your teacher, who will fill it with a measured quantity of hot water. Record the volume. Carefully take the can back to your table.

Step Five: Quickly measure the temperature of the hot water. Record your measurement on the worksheet.

Step Six: Put the tin can full of hot water into the container of room-temperature water. Put the lid back on the container. *Start timing.*

Step Seven: Let exactly ten minutes go by. Then take the lid off the container and quickly measure the temperatures of the water in the tin can and the water in the container. Stir the water with the thermometer before doing so. Measure the temperature of the water in the tin can first. Record your measurements.

Step Eight: Do the calculations on the worksheet.

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Calculation of Rate of Heat Flow

1. Heat Lost by Hot Water in Tin Can

beginning temperature = __________ °C

end temperature = − __________ °C

change in temperature = __________ °C

volume of water = __________ milliliters ≅ x __________ grams

heat lost by hot water = __________ calories

2. Rate of Heat Flow

__________ calories in 10 minutes =

__________ calories per minute.

3. Temperature Difference

beginning temperature of source = __________ °C

beginning temperature of sink = − __________ °C

temperature difference = __________ °C

Comparing Two Units

Objectives

This lesson contributes to students' understanding of the following concepts:

Units of measurement are organized into systems.

The customary system widely used in the United States differs from the International System of Units (SI) used throughout the world.

Anything measurable in one system can be measured in the other.

One Btu is the amount of heat needed to raise the temperature of a mass of one pound of water one degree Fahrenheit (at 39.1°F).

A measurement made in one system of units can be converted to a measurement in another system of units.

One Btu is equivalent to approximately 252 calories.

Format of the Lesson

Discuss existence of different systems of measurement

Measure the length of an object in inches and centimeters

Calculate a conversion factor

Identify properties measured in measuring heat

Define Btu

Conduct activity

Materials Needed

chalkboard

thermometers one for each group of students. These thermometers must be either dual scale (both Celsius and Fahrenheit), or two separate thermometers, one Celsius and one Fahrenheit, are needed.

yardstick

meterstick

anything a bit less than a yard long for the students to measure.

beakers or tin cans, any size larger than a pint, one per group.

graduated cylinders or measuring cups, one per group.

measuring cups at least pint size, one per group.

worksheet **How Many Calories in a Btu?**

Preliminary Discussion

Show the students a yardstick and a meterstick. Ask them what they are. If this has not been part of their education, explain that most of the world measures things using the International System of Units (commonly referred to as the metric system), in which lengths of things are measured in meters. We often use the English system, measuring lengths in inches, yards, and miles. Demonstrate that the meter is divided into 100 subdivisions, called centimeters, and each centimeter into ten millimeters.

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We hope that this is merely review for the students, since what we are about to do (a comparison of the systems) is not the most effective way of introducing the metric system, any more than constant comparison with English is the best way to learn a foreign language. Here, we need to make this comparison to help students see that the physical reality being measured remains the same no matter what system of units is used and, therefore, measurements in different units can be equivalent.

Show the students any physical object one dimension of which is a few inches less than a yard. Give one student the yardstick and ask her to measure this dimension in inches. Record the measurement on the chalkboard, being sure to include the name of the unit, "inches."

Ask another student to measure the object in centimeters. Write that measurement on the board. Ask if we could use these measurements to estimate how many centimeters there are in an inch. Following the students' directions, divide the number of centimeters by the number of inches to get approximately 2.5.

Calories and Btu's

Put the following heading on the board:

MEASURING HEAT IN METRIC
AND CUSTOMARY UNITS

Ask the name of the unit we use to measure heat. (ANS: Calorie.) Make that a heading. Ask what we need to know to measure calories. (ANS: Mass and temperature.) Make those headings on the left, as shown.

Ask what units are used to measure mass when we are calculating calories. (ANS: Grams.) Enter grams on the chart. Ask what units are used to measure mass in customary units. (ANS: Ounces, pounds, tons.) Choose pounds and enter that in the chart.

Ask in what units we measure temperature when we are measuring calories. (ANS: Degrees Celsius.) And in customary units? (ANS: Degrees Fahrenheit.)

The chart should now look like the one below.

MEASURING HEAT IN METRIC
AND CUSTOMARY UNITS

	Metric	Customary
Heat	calorie	???????
Mass	gram	pound
Temperature	°Celsius	°Fahrenheit

Tell the students that American and British engineers needed a unit of heat, too, so they defined one using their customary units. It is called the British thermal unit, or Btu, and it is defined as the amount of heat needed to raise the temperature of one pound of water one degree Fahrenheit (at 39.1°F, the point of maximum density, but we will neglect this).

If I measured my head size in inches, could I convert that to centimeters for my friend in France who wants to send me a hat? How? Could he convert his size to inches for me? How?

Suppose I measure a quantity of heat in calories. Could I convert that to Btu's? (ANS: Yes, if you knew how many calories there were in a Btu.)

Let's do an investigation to try to find a factor for converting Btu's to calories.

How Many Calories in a Btu?

In this investigation, you will learn about another unit used to measure heat, and compare that unit to the calorie.

To do the investigation, you will need:

☐ thermometer that measures in degrees Celsius

☐ thermometer that measures in degrees Fahrenheit. (Some thermometers are marked with two scales, so you may only need one thermometer.)

☐ graduated cylinder

☐ pint measuring cup

☐ beaker or tin can

☐ source of heat

Do you have everything you need?

Procedure

Step One: As you go along, enter your measurements on the form at the bottom of this page.

Step Two: Measure out one pint of water and put it in the beaker. One pint of water has a mass of about one pound. Now measure that same water again using the graduated cylinder. One milliliter of water has a mass of how many grams? Enter the measurements on the worksheet.

Step Three: Measure the temperature of the water in degrees Celsius and also in degrees Fahrenheit. Enter the measurements on the worksheet.

Step Four: Heat the water. Don't try to boil it, just get it warm.

Step Five: Measure the new temperature of the water in degrees Celsius and also in degrees Fahrenheit. Enter the measurements on the worksheet.

Step Six: Do the calculations below.

Calculations

(difference in temperature in degrees Celsius) x (mass in grams) = calories

(difference in temperature in degrees Fahrenheit) x (mass in pounds) = Btu's

	Metric	Customary
end temperature =	____ °C	____ °F
beginning temperature =	– ____ °C	– ____ °F
temperature difference =	____ °C	____ °F
mass =	x ____ grams	x ____ pounds
heat added to water	____ calories	____ Btu

If ____ calories = ____ Btu

then ____ calories = 1 Btu.

Measuring Electricity

Objectives

This lesson contributes to students' understanding of the following concepts:

Energy can be measured.

Electricity can be measured.

We measure electricity when we use it in our homes.

Vocabulary

volts

amperes

amps

watts

kilowatts

kilowatt-hours

Format of the Lesson

Measuring energy

Detecting electricity

Using electricity

Examining rating plates

Assignment

Materials Needed

light bulbs different sizes, marked with wattages.

small appliance optional, with a rating plate.

overhead transparency of rating plates.

worksheet

checklist **Home Appliances.**

Measuring Energy

Review with the class the method they have learned for measuring one form of energy, heat.

Point out some of the aspects of measuring.

Units We had to have well-defined units. What were they? (ANS: The gram, the degree Celsius, the calorie; or the pound, the degree Fahrenheit, the Btu.)

Measurement Technique We had to have a way of measuring those units, like a thermometer for the temperature, and a balance for mass. (For grams of water, we took advantage of the fact that one milliliter of water has a mass of almost exactly one gram.)

So we can measure heat. Do you think it is possible to measure other kinds of energy? (ANS: Yes, sure.)

Why Measure?

One of the first reasons people became interested in measurement was that measurement was necessary in bartering goods and, later, in buying and selling things. Your family buys energy. You buy gasoline by the gallon, for example. What other kinds of energy do you buy? (ANS: Electricity, gas; perhaps propane, coal, wood, or other forms.)

Since we buy electricity, we must be able to measure it. Let's do some detective work and see if we can find the units that are used to measure electricity.

Show the class some light bulbs. Point out that some bulbs give more light than others. When we're describing a light bulb, how do we say that this one (indicate the 100-watt bulb) is bigger or brighter than this one (a 40-watt bulb)? (ANS: Watts. One is a 40-watt light bulb and the other is a 100-watt.)

Point out to the class that the markings on the light bulbs indicate this answer is correct; for some reason, the bulbs have the word "watt" on them. Watt must have something to do with how powerful the light bulb is.

Checking an Appliance

If you have been able to bring in a small appliance, give it to some students and ask if they can find any electrical information written on it. Ask them to read what they find aloud. Note the significant numbers and units on the board, such as:

115 volts 1.5 amps (or amperes) 170 watts

Point out that the word watts is here again, with two additions — volts, and amperes.

Explain that people often use the nickname "amps" to mean amperes, and you may hear or see it either way. Amps and amperes mean the same thing.

Almost everything in our house that uses electricity will have on it information about volts, amperes, and watts.

Put on the overhead transparency of the rating plates. Go through the plates one by one, asking a student to read the volts, amperes, and watts, if all are given.

Homework Assignment

Pass out the worksheet and the checklist. Go over the assignment with the students. Suggest that they use the time remaining in the period to list on their worksheets the names of some appliances they know they have at home, so that they will have a head start when they get home.

Point out to the students that some plates may only give amperes (or amps) and not watts; and others may give only watts and not amperes. Just copy down whatever is on the rating plate.

Point out that we will not be filling in the last two columns this week, but we will later. Therefore, these worksheets should be carefully preserved for later use. You may wish to collect and save them for this purpose, although a question of privacy arises if you do. It is probably best to tell the students explicitly that you will not collect the sheets and that they do not have to share them with other students. Of course, you will discourage any who-owns-the-most contests.

If some parents will not permit their children to complete these worksheets, ask those students to go to a small appliance store and copy information from the appliances on sale.

Collect the checklists at the end of the period; they can be reused.

116

MODEL	TYPE & SERIAL	AMPS
3760	A 18685021	8.0
		VOLTS 120 AC
		HERTZ 25-60

UL **THE WONDER COMPANY**
East Oshkosh, Wisconsin 65342

Panavisic Color TV
Model CT-911V AC 120V 60 Hz 180 W
Product complies with D HEW rules 21 CFR part 278 applicable at date of manufacture.
Honisuma Electric Industrial Co., Ltd.
Osaka, Japan MG 413

Jones Crown Corp.

Covered by one or more of the following US patents: 3,181,861; 3,584,317; 3,823,754; 4,581,448; 4,601,217; 5,707,321; 5,723,968. Double Insulated. When servicing, use only identical replacement parts. Grounding not required.
Printed in USA

Electric typewriter
Model 9E
Volts 117 AC
Hz 60
Amps 1.0
Watts 60

523654 REV C

Farmerware®
Model No. 264
120 volts 1600 watts 50-60 HZ A C
Made in USA
Farmerware
Division of MCA
Brooklyn, NY 17001
UL listed
toaster
342A

Name:

Measuring Electricity

Worksheet

Examine all the appliances you can find in your home (ignore lights). Look for the nameplate on the appliance, which may list volts and amperes, and watts the appliance consumes. Some appliances may be so big you can't move them to find the plate; don't worry about that. Leave blanks where there is no information on the appliance. Put these sheets in a safe place and save them for later in the year.

Name of Appliance	Volts	Amps	Watts	Hours per year	Kilowatt-hours per year

A Checklist of Appliances

Most people don't realize how many appliances they have. To help you make your own record of the appliances in your home accurate, here is a list of some common and not so common appliances.

Kitchen

- refrigerator
- freezer
- dishwasher
- electric range
- electric mixer
- toaster
- coffee maker
- waffle iron
- electric oven
- microwave oven
- blender
- Crock-pot®
- hot-dog cooker
- hamburger maker
- deep-fat fryer
- electric knife
- electric can opener
- electric clock
- trash compactor
- garbage disposal
- egg cooker
- electric frying pan
- electric yogurt maker
- electric ice cream maker
- popcorn maker
- food processor
- electric crepes maker
- electric coal starter
- rotisserie
- toaster oven
- oven vent fan

Bathroom

- electric shaver
- electric toothbrush
- hair dryer/hair blower
- hair curler
- tooth irrigator
- manicure machine
- electric facial machine
- electric shave-cream heater
- portable electric heaters

Hobby

- sewing machine
- electric drill
- electric saw
- slide projector
- movie projector
- tape recorder
- calculator
- CB radio
- electric exercise machine

Living Area

- television set
- phonograph or stereo
- radio
- computer games
- toys
- air conditioner
- fan
- electric bug-killer
- ion generator
- burglar alarm
- smoke detector

Bedroom

- electric heating pad
- electric blanket
- sun lamp
- electric bed

Utility Room, Basement

- vacuum cleaner
- electric broom
- washing machine
- dryer
- iron
- electric water heater
- humidifier
- oil burner
- fans
- door bell
- electric hedge clipper
- heat pump
- central air conditioner

Outdoor

- electric barbecue
- swimming pool heater
- sauna
- garage-door opener

Annual Energy Requirements of Electric Household Appliances

	Average Wattage	Estimated kWh Consumed Annually
Food Preparation		
blender	300	1
broiler	1,140	85
carving knife	92	8
coffee maker	894	106
deep fryer	1,448	83
dishwasher	1,201	363
egg cooker	516	14
frying pan	1,196	100
hot plate	1,200	90
mixer	127	2
oven, microwave (only)	1,450	190
range		
with oven	12,200	1,175
with self-cleaning oven	12,200	1,205
roaster	1,333	60
sandwich grill	1,161	33
toaster	1,146	39
trash compactor	400	50
waffle iron	1,200	20
waste dispenser	445	7
Food Preservation		
freezer (15-21 cu. ft.)		
chest-type, manual defrost upright-type	—	1,320
manual defrost	—	1,320
automatic defrost	—	1,985
refrigerators/freezers		
manual defrost 10-15 cu. ft.	—	700
automatic defrost, 16-18 cu. ft.	—	1,795
automatic defrost, 20 cu. ft. and up	—	1,895
Laundry		
clothes dryer	4,856	993
iron (hand)	1,100	60
washing machine (automatic)	512	103
washing machine (nonautomatic)	286	76

	Average Wattage	Estimated kWh Consumed Annually
water heater	2,475	4,219
water heater (quick recovery)	4,474	4,811
Comfort Conditioning		
air cleaner	50	216
air-conditioning (room)	860	860*
bed covering	177	147
dehumidifier	257	377
fan (attic)	370	291
fan (circulating)	88	43
fan (rollaway)	171	138
fan (window)	200	170
heater (portable)	1,322	176
heating pad	65	10
humidifier	177	163
Health and Beauty		
germicidal lamp	20	141
hair dryer	381	14
heat lamp (infrared)	250	13
shaver	15	0.5
sun lamp	279	16
tooth brush	1.1	1.0
vibrator	40	2
Home Entertainment		
radio	71	86
radio/record player	109	109
television		
black & white		
tube-type	100	220
solid-state	45	100
color		
tube-type	240	528
solid-state	145	320
Housewares		
clock	2	17
floor polisher	305	15
sewing machine	75	11
vacuum cleaner	630	46

The estimated annual kilowatt-hour consumption of the electric appliances listed is based on normal usage. When using these figures for projections, such factors as the size of the specific appliance, the geographical area of use, and individual usage should be taken into consideration. Note that the wattages are not additive since all units are normally not in operation at the same time.

*Based on 1000 hours of operation per year. This figure will vary widely depending on area and specific size of unit. See EEI-Pub #76-2 "Air Conditioning Usage Study" for an estimate for your location.

Source: EEI-pub #75-61, Edison Electric Institute, 90 Park Avenue, New York, N.Y. 10016.

Meter Reading

Objectives

This lesson contributes to the students' understanding of the following concepts:

Energy must be measured to be bought and sold.

We consume energy at different rates at different times.

As a result of this lesson, students will be able to read the typical watt-hour meter. This skill requires the following understandings:

The dials of the meter read from left to right, like the digits in the numeral representing the reading.

Some of the dials read counterclockwise and some read clockwise.

When a pointer is between numerals, the reading is the lesser of the two numerals.

When a pointer seems to be exactly on a number, look at the dial to the right. If the pointer on that dial is between 0 and 1, it has passed zero and the reading on the dial to the left is the numeral the pointer seems to be on. If the pointer on the dial to the right is between 9 and 0, it has not reached zero yet and the reading for the dial to the left should be one less than the numeral it seems to be on.

Some readings must be multiplied by 10 or 100, as indicated on the meter face.

(Do not ask students to memorize these rules.)

Format of the Lesson

Discuss need for measuring in trade

Relate to trade in energy in the household

The watt and watt-hour

The kilowatt-hour

Meter-reading worksheet

Begin data collection for consumption patterns lesson

Materials Needed

worksheet **Meter Reading**, one per student.

worksheet **Electric Diary: One Day**, one per student.

worksheet **Electric Diary: One Week**, one per student.

Buying and Selling Energy

Discuss the importance of measurement in trade.

Ask what kinds of energy our families buy.

Summarize that, to buy this energy, we must be able to measure it.

What Units Are Used to Buy And Sell Electrical Energy?

Establish that a unit of measurement is needed to buy and sell electrical energy.

Review the electrical units we have learned: the volt, the ampere, and the watt.

Watts measures the amount of power an appliance (such as a light bulb) consumes. To find how much energy is consumed, we have to know how long the appliance was on. The greater the wattage of a light bulb, the faster it consumes energy. The longer it is on, the more energy it consumes.

So, we can define a unit of electrical energy. One watt-hour is the amount of electrical energy that would be consumed in one hour if we were using it at a rate of one watt.

Put the following equation on the chalkboard.

watts x hours = watt-hours

If we burn a 40-watt light bulb for two hours, how many watt-hours have we used? (ANS: 80 watt-hours.)

We can also have watt-seconds, or watt-minutes. But all these are too small to be useful in ordinary life, so we use an even bigger unit, the kilowatt-hour.

What does the prefix "kilo" mean? (ANS: 1000.) What is a kilometer? A kilogram?

The Kilowatt-Hour

How much electrical energy does a kilowatt-hour represent?

A 1000-watt light bulb burning for one hour.

A 1-watt light bulb burning for 1000 hours.

A 100-watt light bulb burning for how many hours? (ANS: 10 hours.)

A 50-watt light bulb burning for how many hours? (ANS: 20 hours.)

So there are many different ways of using up a kilowatt-hour.

Measuring Kilowatt-hours

Some device is needed to measure the kilowatt-hours we buy from the electric company. What is that device? (ANS: The electric meter.)

Tell the class that they will learn how (or, perhaps, review how) to read the electric meter. Pass out the worksheets. We suggest these be completed in class while your help is available.

Energy Consumption

When you are satisfied that most of the students can read a meter, pass out the other two worksheets. Both provide practice in meter-reading; the "week" is easier to do than the "day." Try to avoid getting all Saturdays for the day sheet, since Saturday is not a typical weekday. You may wish to have some students read the school's meter.

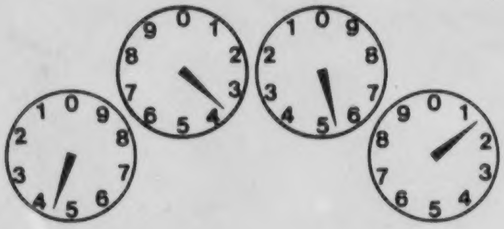
Be aware of the importance of protecting privacy when using these sheets.

Later in the unit, students will study their sheets to discover patterns in their use of energy.

Name:

Meter Reading

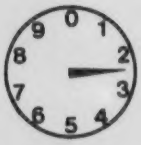
This exercise is for people whose utility meters look like this:

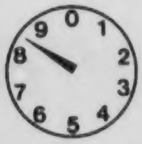

1 0 9 8 7 6 5 4 3 2
9 0 1 2 3 4 5 6 7 8
1 0 9 8 7 6 5 4 3 2
9 0 1 2 3 4 5 6 7 8

In this exercise, you will learn how to read your meter.

1. Each dial of the meter has a little hand. Usually the hand is between two numbers. Then the hand is indicating the number which is less, just like a clock.

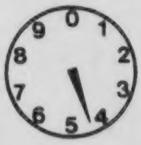
Here's a dial indicating the number 2.

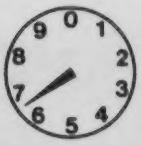

9 0 1 2 3 4 5 6 7 8


9 0 1 2 3 4 5 6 7 8

What is the reading on this dial? ________

What is the reading on this dial? ________

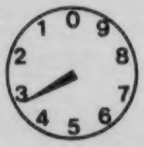

9 0 1 2 3 4 5 6 7 8


9 0 1 2 3 4 5 6 7 8

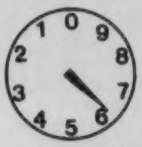
What is the reading on this dial? ________

2. Your meter will have a row of four or perhaps five dials. Look at the meter face at the top of the page. On the dial on the far right, the numbers go around just as they do on a clock. But look at the dial next to it. The numbers go around in the opposite direction. It reads counterclockwise. Whether the numbers go clockwise or counterclockwise, always read the smaller of the two numbers the hand is between.

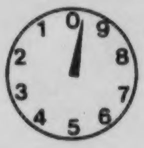
Here are some more dials.
What does this one read? ________



What is the reading on this dial? ________



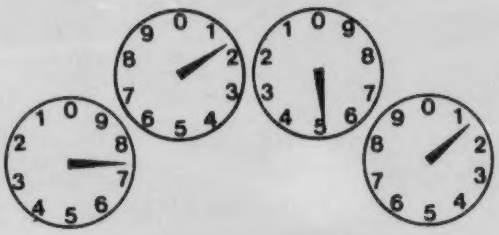
What is the reading on this dial? ________



3. The dials are arranged left to right in the same order as the digits in the number. Write down the numbers in order from left to right.

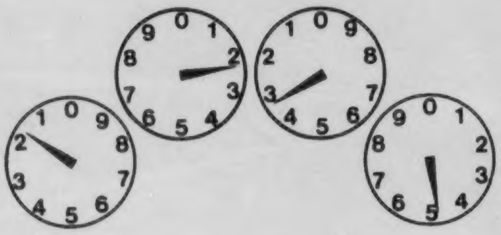
What does this meter read?

_____ _____ _____ _____



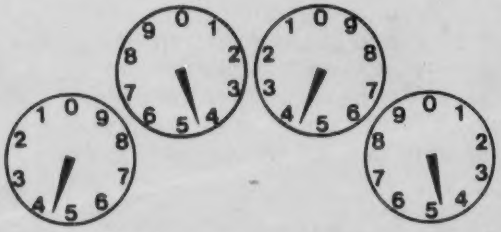
What does this meter read?

_____ _____ _____ _____



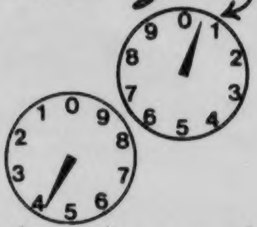
What does this meter read?

_____ _____ _____ _____

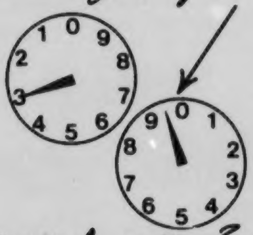


4. Sometimes a hand seems to be pointing exactly at a number. Has it reached it yet or not? To find out, look at the dial to the right. If the hand on the dial to the right has already passed zero, then you should put down the number the other hand seems to be pointing at. If it hasn't, put down the next lower number.

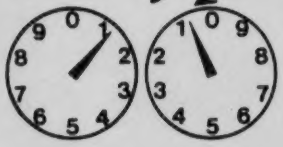
What do these two dials read? _____ _____


has just passed zero!

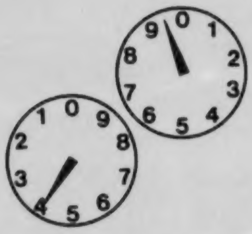
What do these two dials read? _____ _____


has not reached zero yet.

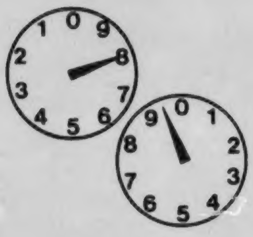
What do these two dials read? _____ _____


has this passed zero?

What do these two dials read? _____ _____

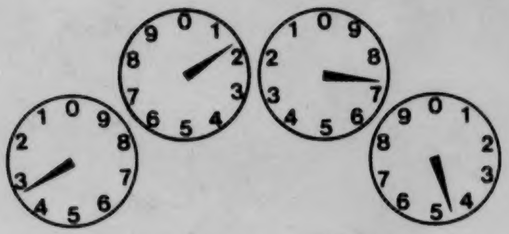


What do these two dials read? _____ _____

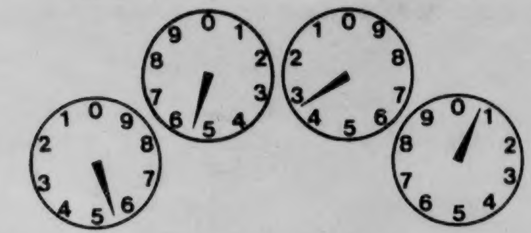


5. In some areas, utilities may have different rules for reading the last dial. The meter-person may be instructed to put down whichever number the hand is closest to, or the highest of the two numbers the hand is between. What is the rule in your area?

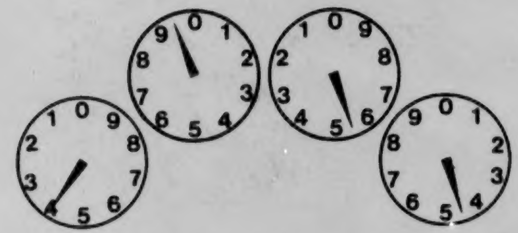
6. Now we're ready to read meters. Read the following meters:



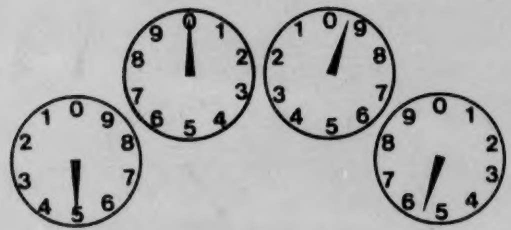
____ ____ ____ ____



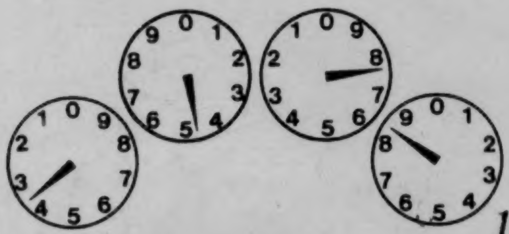
____ ____ ____ ____



____ ____ ____ ____

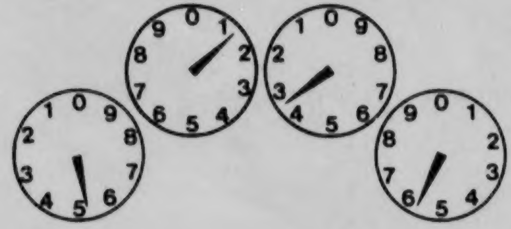


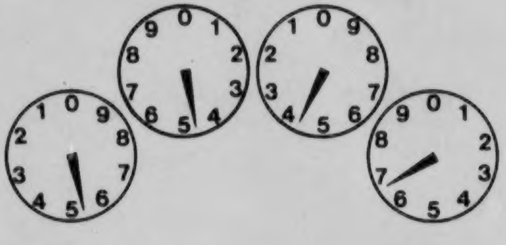
____ ____ ____ ____



____ ____ ____ ____

7. To find out how much energy we've used since the last time the meter was read, we have to subtract the old reading from the new reading. How much electricity did these houses use?

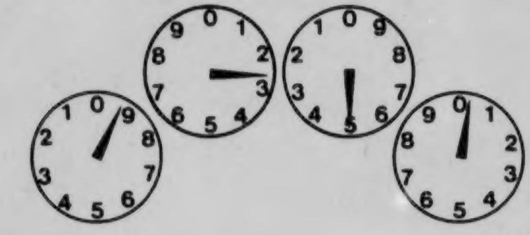


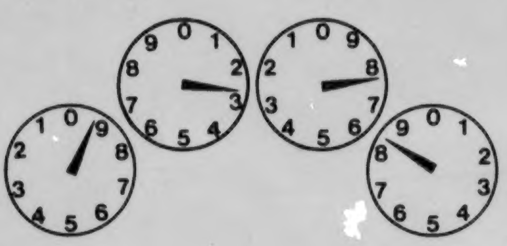


______

______

January 1 ___ ___ ___ ___ February 1 ___ ___ ___ ___ ______kWh

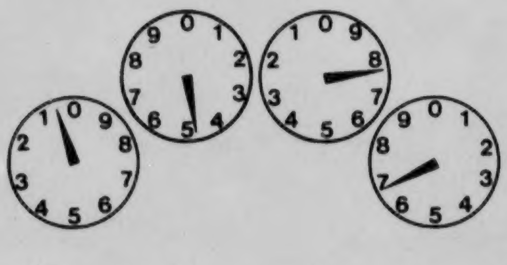


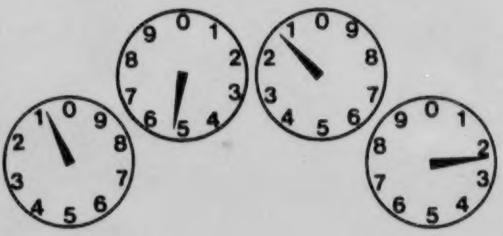


______

______

June 30 ___ ___ ___ ___ July 30 ___ ___ ___ ___ ______kWh



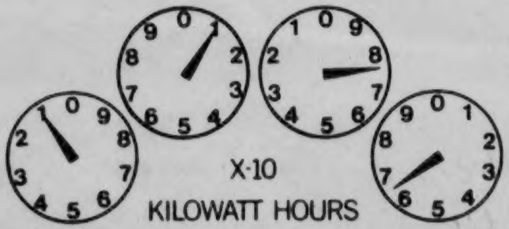


______

______

September 13 ___ ___ ___ ___ October 13 ___ ___ ___ ___ ______kWh

8. Some meters are marked "X-10" or "K-10." This means that, instead of reading kilowatt-hours, the meter reads tens (or twenties) of kilowatt-hours. If your meter has such a marking, you must multiply the reading by 10 (or, if the meter is marked "K-20," multiply by 20).



___ ___ ___ ___

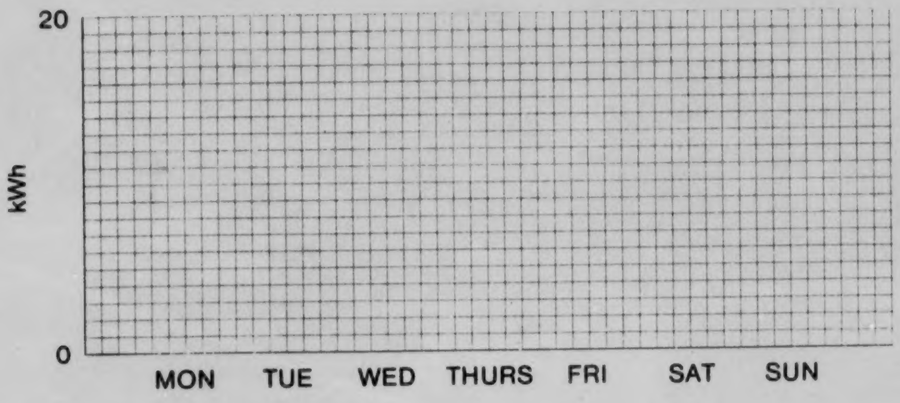
Electric Diary: One Week

During one week, every day, at the same time of day, read your family's electric meter. Of course, if you wanted to measure exactly by days, you would have to read the meter at midnight. But a good practical time to read it is before going to school or after dinner.

Date I began: ____________________

Day of Week	Time of Reading	Reading	kWh Used in Last 24 Hours
(Sunday)			
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

Use this form to make a bar graph of your weekly electrical consumption.



Do you notice any bumps? What caused them?

Save this sheet. In a different season, do the activity again and see if your pattern of consumption has changed.

Electric Diary: One Day

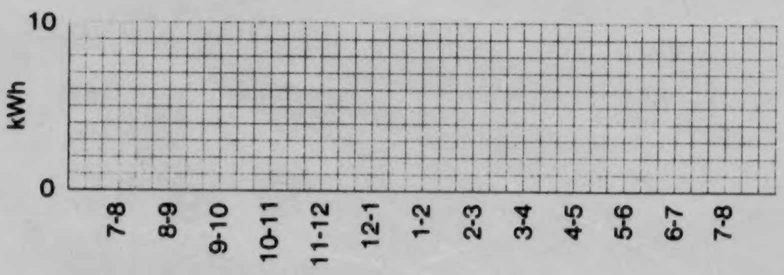
Choose one day, and read your electric meter every hour on the hour. Record your readings below. (If your meter does not have a dial that counts individual kilowatt-hours, you may not be able to complete this worksheet.)

Day of the Week: ______________________

	Readings
7 AM	
8 AM	
9 AM	
10 AM	
11 AM	
Noon	
1 PM	
2 PM	
3 PM	
4 PM	
5 PM	
6 PM	
7 PM	
8 PM	

	Consumption
7-8	
8-9	
9-10	
10-11	
11-Noon	
Noon-1	
1-2	
2-3	
3-4	
4-5	
5-6	
6-7	
7-8	

Use this form to make a bar graph of your electrical consumption that day.



Save this sheet. On a different day of the week, or in a different season, do the activity again and see if your pattern of consumption has changed.

Reading Utility Bills

Objectives

The object of this lesson is to develop the students' ability to extract information from bills for electricity and natural gas of the type used in their community.

Format of the Lesson

Discuss buying energy at home

Discuss measuring electric power

Show transparency of electric bill and discuss features

Complete electricity worksheet

Discuss measuring the energy in gas

Pass out gas-meter worksheet

Show transparency of gas bill and discuss features

Pass out gas-bill worksheet

Materials Needed

chalkboard

utility bills if you cannot find people willing to donate their old bills for students' scrutiny, call the utility company educational representative and ask the company to send you sample bills. If that fails, photocopy a bill, paint out the name and numbers with a product like Liquid Paper, and insert new, plausible figures.

overhead transparencies of electric and gas utility bills.

worksheets one per student. The sheets referring to bills are provided only as samples. the forms used in your community will probably differ from those shown, and may not include all the information asked for.

Reading an Electric Bill

Reading a Gas Meter

Reading a Gas Bill

What Does It Cost to Take a Warm Bath? (optional)

Gas Diary: One Week

Teacher Background

Utility bills are not standardized across the United States, and some bills may not include all the items on the bills described in this lesson plan. Some may contain additional information. It is important that you study bills used in your locality prior to the lesson, so that you know what information they provide and exactly where on the bill it can be found. Almost all utilities will provide interpretive literature about their bills on request.

Buying Energy at Home

Ask the class what forms of energy their families buy. List these on the board. They may include gasoline, food and, in some areas, coal or propane, electricity, and natural gas.

Ask them how we know how much we have bought. Bring out that we must have a unit of measure and a way of measuring.

Measuring Electric Power

Ask the class what units can be used to measure electrical energy. (ANS: Watt-hours, or kilowatt-hours.)

In fact, that is how we buy our electricity, by the kilowatt-hour.

Ask students to describe when and how we pay for our purchases of electricity.

Discuss Electric Bill

Show an overhead transparency of a local electric bill (not the same one you have reproduced for the worksheet). Go over the various entries on the bill, asking students what they mean. Most are rather straightforward and will provide a chance for everybody in the class to contribute.

Some, however, are not so obvious. These might include:

The rate schedule. Discuss why different customers may pay different prices per kilowatt-hour. (In the past, big users always paid less. Now they sometimes pay more, so be careful about making generalizations.) Discuss how rates are set. It is helpful to have a copy of the rate schedules available for students to look at. These can be obtained from your public utilities commission.

Lifeline rates are a device used in some states to provide a basic amount of energy to all households at a lower than usual cost.

To avoid having to read the meter each month, yet have monthly billing, bills in some areas are based on *estimates*, which are corrected when the meter is read. In that case, the bill will have a code to show if it is based on a reading or on an estimate.

Pass out the worksheet on the electric bill. You may wish students to complete it as homework, or you may want to do this in class and save the discussion of the gas bill for the following class. In many classes, an entire period will have been consumed by this point.

Discuss Measuring the Energy in Natural Gas

We buy gasoline by the gallon, and electricity by the kilowatt-hour. What units do you think the gas company uses to measure the gas it sells?

List responses on the chalkboard. One way is to measure the volume of the gas.

[If some of your students seem a bit hazy on the concept of volume, you may wish to go through the following review:

Ask the class to name a unit we use to measure *length*. Someone will mention feet, or a foot. Apply the foot measurement to some real object, like the classroom: it is about so many feet long, and so many feet wide. Now suppose, instead of length, we wanted to measure *area* (to put new flooring in the classroom, for example). What unit would we use then?

Students will volunteer "square feet." Do a rough calculation of the area of the classroom floor, using the estimates of length and width already made.

Now ask what units we could use to measure the *volume* of air in the room. If students do not suggest "cubic feet," supply the term and then discuss what a cube is. Calculate the number of cubic feet of air in the classroom.]

Measuring the Gas We Buy

Homes and apartments using gas will have a gas meter. The school itself may have a gas meter that the class could visit. What would we expect the gas meter to measure? (ANS: Cubic feet of gas.)

Tell the class that reading a gas meter is much like reading an electric meter, even through the faces look a little different. Pass out the worksheet, **Reading a Gas Meter**, and ask students to complete it as homework.

Only a very few gas utilities sell gas by the cubic foot. If yours does, proceed from this point directly to looking at a typical bill, preferably as an overhead transparency.

However, gas utilities who get gas from a number of different sources, or who have large differences in altitude in their service areas, cannot bill directly for cubic feet. The reasons should be discussed with the students.

1. Natural gas is a mixture of different substances. Some gases produce more heat than others when they burn, and so are worth more.

2. Gas reaching the burner at sea level will be more compressed than gas reaching a burner on a mountaintop. At sea level, you will get more gas molecules per cubic foot and so more heat per cubic foot.

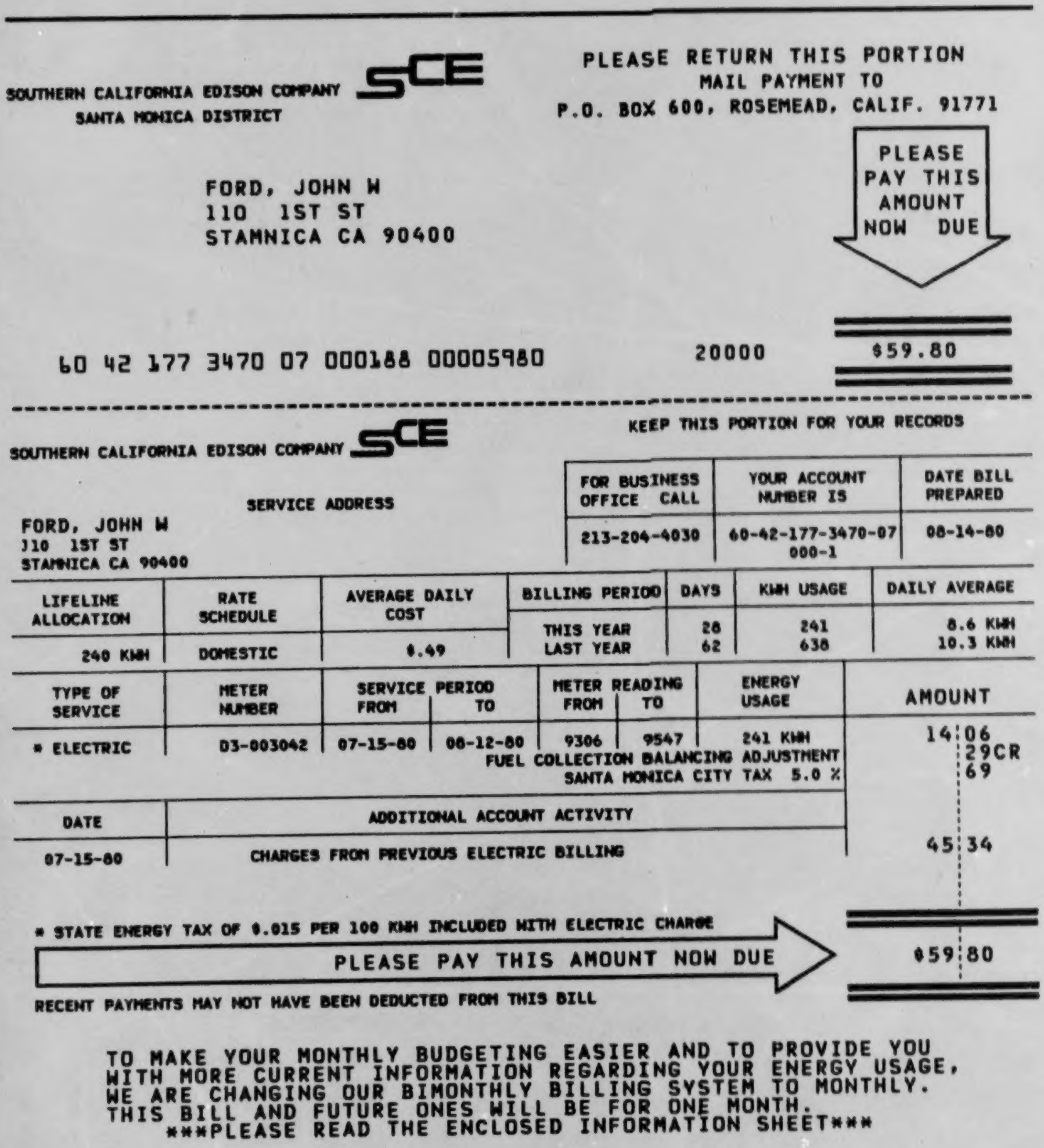
In order to pay for only the heat we are getting, we need to take into account how many molecules are in a cubic foot of the gas we get, and what kind of molecules they are.

To do this, the gas company uses a *billing factor*. The billing factor is a number used to convert cubic feet of the kind of gas you get at your home, at your altitude, to Btu's. Actually, gas companies don't use Btu's, but a unit called the *therm*, which is simply 100,000 Btu's. The billing factor is the number of therms that you could get burning 100 cubic feet of the gas delivered to you.

So the gas meter measures the number of cubic feet you've used, the gas bill tells you how many cubic feet that was, converts those cubic feet to therms, and then charges you for them according to your rate schedule.

Projects for Independent Investigation

1. Make a box representing a cubic foot.
2. Make a graph showing the daily consumption of electricity and gas in your school. Put it up in the hallway and update it every day.



SOUTHERN CALIFORNIA EDISON COMPANY SCE
SANTA MONICA DISTRICT

PLEASE RETURN THIS PORTION
MAIL PAYMENT TO
P.O. BOX 600, ROSEMEAD, CALIF. 91771

FORD, JOHN W
110 1ST ST
STAMNICA CA 90400

PLEASE PAY THIS AMOUNT NOW DUE

60 42 177 3470 07 000188 00005980 20000 $59.80

KEEP THIS PORTION FOR YOUR RECORDS

SOUTHERN CALIFORNIA EDISON COMPANY SCE

SERVICE ADDRESS

FORD, JOHN W
110 1ST ST
STAMNICA CA 90400

FOR BUSINESS OFFICE CALL	YOUR ACCOUNT NUMBER IS	DATE BILL PREPARED
213-204-4030	60-42-177-3470-07 000-1	08-14-80

LIFELINE ALLOCATION	RATE SCHEDULE	AVERAGE DAILY COST	BILLING PERIOD	DAYS	KWH USAGE	DAILY AVERAGE
240 KWH	DOMESTIC	$.49	THIS YEAR	28	241	8.6 KWH
			LAST YEAR	62	638	10.3 KWH

TYPE OF SERVICE	METER NUMBER	SERVICE PERIOD FROM	SERVICE PERIOD TO	METER READING FROM	METER READING TO	ENERGY USAGE	AMOUNT
* ELECTRIC	D3-003042	07-15-80	08-12-80	9306	9547	241 KWH	14 06
FUEL COLLECTION BALANCING ADJUSTMENT							29CR
SANTA MONICA CITY TAX 5.0 %							69

DATE	ADDITIONAL ACCOUNT ACTIVITY	AMOUNT
07-15-80	CHARGES FROM PREVIOUS ELECTRIC BILLING	45 34

* STATE ENERGY TAX OF $.015 PER 100 KWH INCLUDED WITH ELECTRIC CHARGE

PLEASE PAY THIS AMOUNT NOW DUE $59 80

RECENT PAYMENTS MAY NOT HAVE BEEN DEDUCTED FROM THIS BILL

TO MAKE YOUR MONTHLY BUDGETING EASIER AND TO PROVIDE YOU WITH MORE CURRENT INFORMATION REGARDING YOUR ENERGY USAGE, WE ARE CHANGING OUR BIMONTHLY BILLING SYSTEM TO MONTHLY. THIS BILL AND FUTURE ONES WILL BE FOR ONE MONTH.

PLEASE READ THE ENCLOSED INFORMATION SHEET

Reading an Electric Bill

1. Each of the company's electric meters is numbered. This is a bill for all the electricity that went through one particular meter. What was the number of that meter? ______________.

2. The electric company identifies this customer by an account number.

What is that number? ______________.

3. What was the date of the previous meter reading? ______________.

What was the reading on that date? __________ kilowatt-hours.

4. What was the date of this meter reading? ______________.

What was the reading? __________ kilowatt-hours.

5. How many days does this bill cover? __________ days.

6. How many kilowatt-hours have been used during that period? __________ kilowatt-hours.

7. How many kilowatt-hours did the customer use in this time period

last year? __________ kilowatt-hours.

Is the customer's consumption rising or falling? ____________.

8. What number should the customer call if he has any questions about this bill?

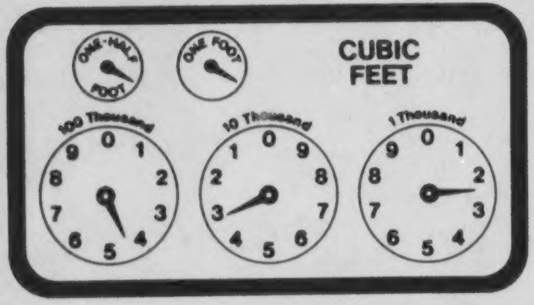
____________________.

9. How much did the customer pay in taxes for the electricity? ______________.

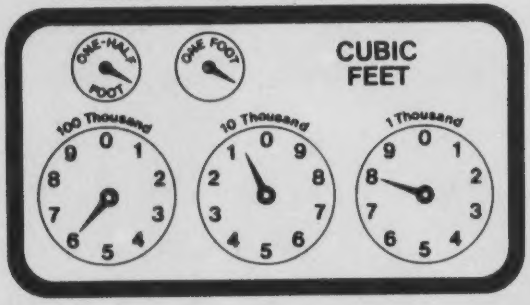
10. What rate schedule applied to this purchase? ______________________________.

Now look at a bill for your own family and see if you can find the same information on it.

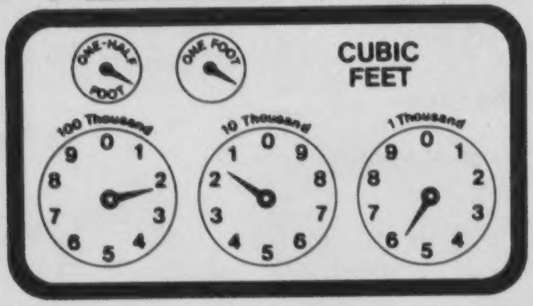
3. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

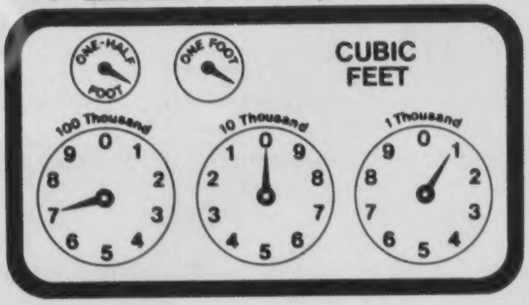
4. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

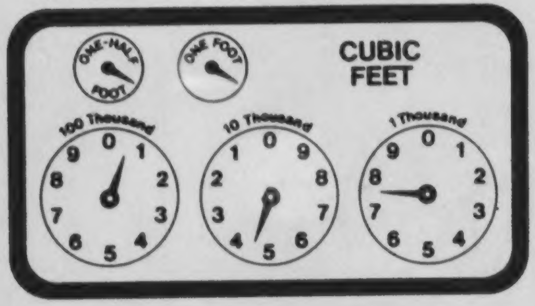
5. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

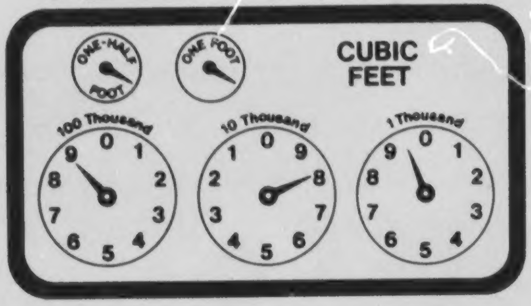
6. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

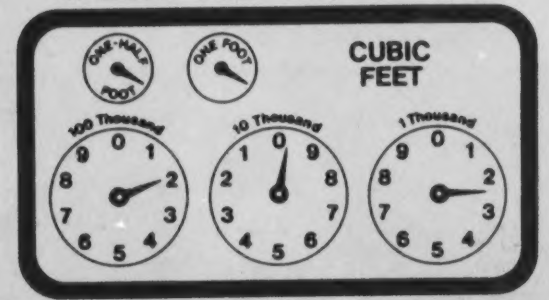
7. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

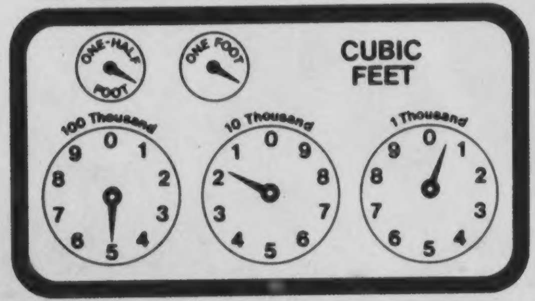
8. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

9. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

10. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

Reading a Gas Meter

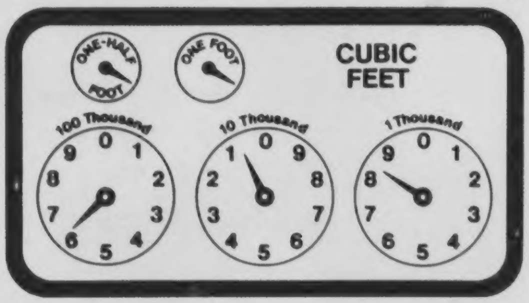
You will find it easy to learn how to read your gas meter, since you already know how to read an electric meter. The hands on the dials of the gas meter go around the same way as the hands on the electric meter, and follow the same rules:

If the hand is between two numbers, the reading is the lower of the two numbers.

The dials read from left to right, just like the numerals on a page.

If a hand seems to be exactly on a number, look at the dial to the right. If the hand on that dial is between 0 and 1, the reading is the number the hand is on. If the hand on the other dial is between 9 and 0, the reading is the next lower number.

Most gas meters look something like this:

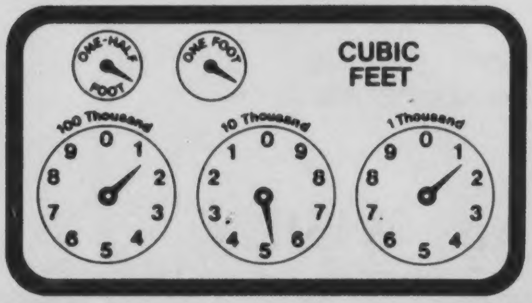

ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

On the top are two dials all by themselves. They are marked "one-half cubic foot" and "one cubic foot." The gas company uses these dials to check the meters, to make sure they are accurate. They are not used when you read the meter.

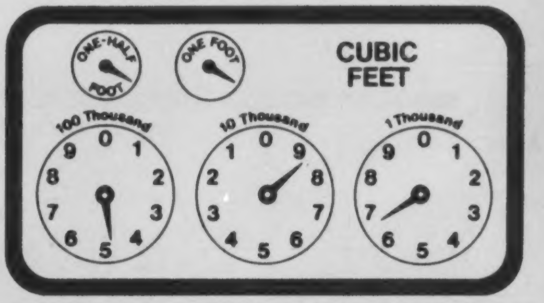
Notice that the dial on the far right is marked "1 Thousand." This means that each time the pointer on this dial goes around, a thousand cubic feet of natural gas has been used. The "5" on this dial therefore means 500 cubic feet. Because there are no hundred's or ten's dials, we must add two zeros to our reading to get the correct number of cubic feet.

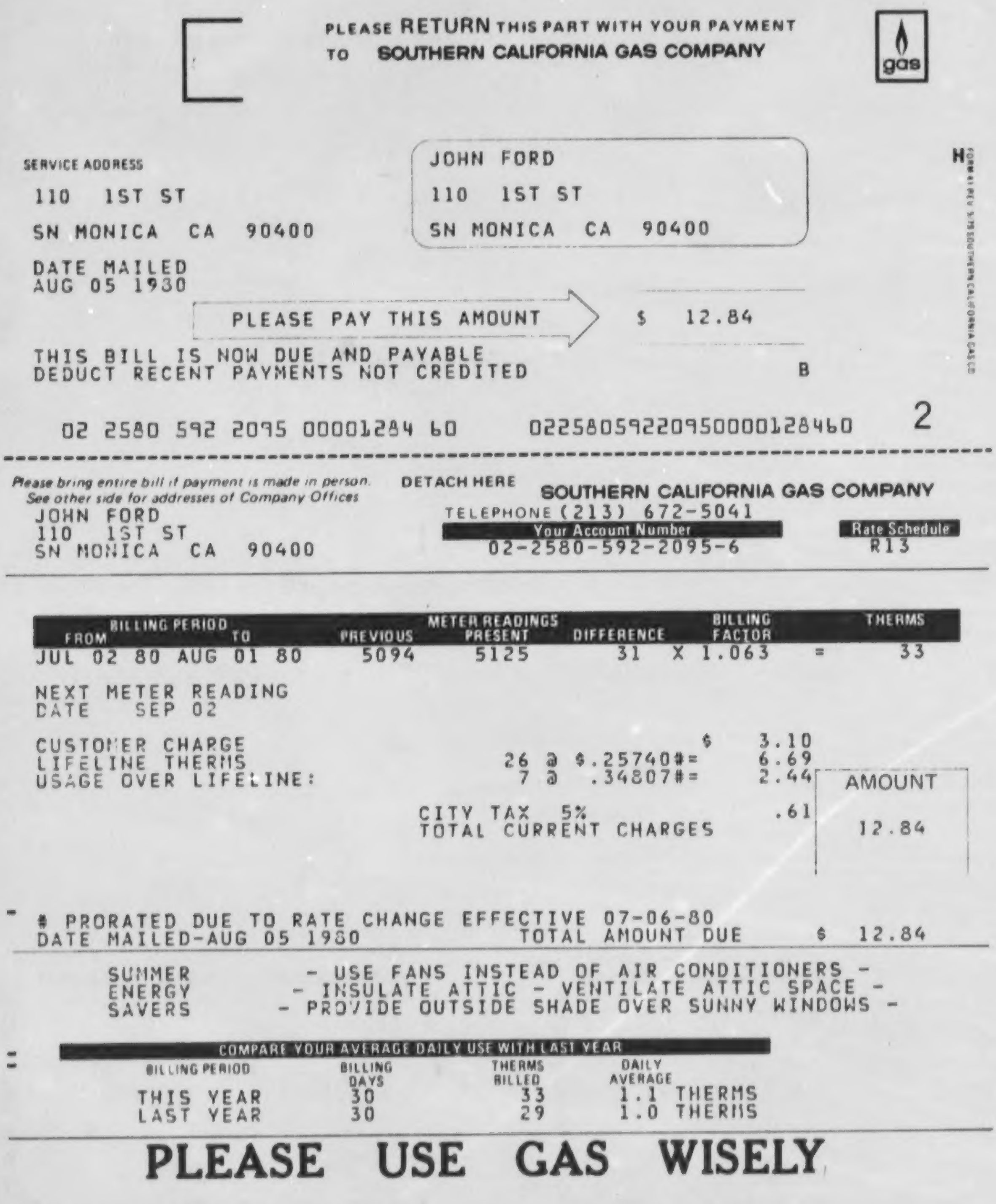
Here are some meters. Write down their readings in the blanks provided.

1. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand

2. ______ ______,______ 00


ONE-HALF FOOT
ONE FOOT
CUBIC FEET
100 Thousand
10 Thousand
1 Thousand



PLEASE **RETURN** THIS PART WITH YOUR PAYMENT
TO **SOUTHERN CALIFORNIA GAS COMPANY**

gas

H FORM 41 REV. 5/78 SOUTHERN CALIFORNIA GAS CO

SERVICE ADDRESS
110 1ST ST
SN MONICA CA 90400

JOHN FORD
110 1ST ST
SN MONICA CA 90400

DATE MAILED
AUG 05 1980

PLEASE PAY THIS AMOUNT $ 12.84

THIS BILL IS NOW DUE AND PAYABLE
DEDUCT RECENT PAYMENTS NOT CREDITED B

02 2580 592 2095 00001284 60 0225805922095000128460 2

DETACH HERE

Please bring entire bill if payment is made in person.
See other side for addresses of Company Offices

JOHN FORD
110 1ST ST
SN MONICA CA 90400

SOUTHERN CALIFORNIA GAS COMPANY
TELEPHONE (213) 672-5041

Your Account Number	Rate Schedule
02-2580-592-2095-6	R13

BILLING PERIOD FROM	TO	METER READINGS PREVIOUS	PRESENT	DIFFERENCE		BILLING FACTOR		THERMS
JUL 02 80	AUG 01 80	5094	5125	31	X	1.063	=	33

NEXT METER READING
DATE SEP 02

CUSTOMER CHARGE		$ 3.10	
LIFELINE THERMS	26 @ $.25740#=	6.69	
USAGE OVER LIFELINE:	7 @ .34807#=	2.44	AMOUNT
CITY TAX 5%		.61	
TOTAL CURRENT CHARGES			12.84

PRORATED DUE TO RATE CHANGE EFFECTIVE 07-06-80
DATE MAILED-AUG 05 1980 TOTAL AMOUNT DUE $ 12.84

SUMMER - USE FANS INSTEAD OF AIR CONDITIONERS -
ENERGY - INSULATE ATTIC - VENTILATE ATTIC SPACE -
SAVERS - PROVIDE OUTSIDE SHADE OVER SUNNY WINDOWS -

COMPARE YOUR AVERAGE DAILY USE WITH LAST YEAR

BILLING PERIOD	BILLING DAYS	THERMS BILLED	DAILY AVERAGE
THIS YEAR	30	33	1.1 THERMS
LAST YEAR	30	29	1.0 THERMS

PLEASE USE GAS WISELY

Reading a Gas Bill

1. Every customer of the gas company has a different account number (in a big city, there are often people with similar names). What is this customer's account number?

____________________.

2. What telephone number should they call if they have a question about their gas bill?

____________________.

3. What was the date of the last meter reading? ____________________.

4. What was the meter reading? ____________________.

5. How many days have gone by between meter readings? ________________ days.

6. How many cubic feet of gas have been used during the time between meter readings? (Remember that the numbers on the bills are *hundreds* of cubic feet.)

________________ cubic feet.

7. Find the number used to convert the volume of gas metered to its heating value. What is it for this address? ____________________.

What is it called? ____________________.

8. How many therms did the customer use? ________________ therms.

9. How many Btu's were obtainable from the gas this customer bought? (Remember 1 therm = 100,000 Btu.) ________________ Btu's.

10. What did the customer pay for each of the first 26 therms? $____________________.

11. What did the customer pay for each therm after 26? $____________________.

12. How much were the taxes? $____________________.

13. How much does the customer owe in all? $____________________.

14. Did the customer use more or less energy this year than last year? ____________________.

What percent of the customer's average daily consumption last year was the consumption this year? ________________ %.

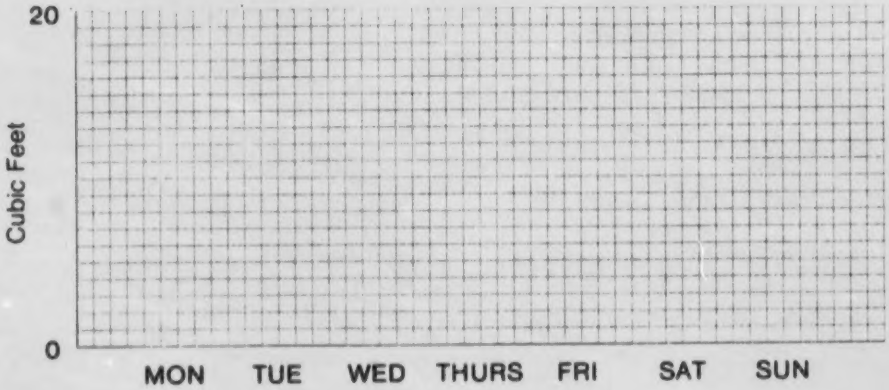
Gas Diary: One Week

During one week, every day, at the same time of day, read your family's gas meter. Of course, if you wanted to measure exactly by days, you would have to read the meter at midnight. But a good practical time to read it is before going to school or after dinner.

Date I began: ____________________

Day of Week	Time of Reading	Reading	Cubic Feet Used In Last 24 Hours
(Sunday)			
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

Use this form to make a bar graph of your weekly gas consumption.



Do you notice any bumps? What caused them?

Save this sheet. In a different season, do the activity again and see if your pattern of consumption has changed.

Name:

Gas Diary: One Day

Choose one day, and read your gas meter every hour on the hour. Record your readings below.

Day of the Week: ______________________

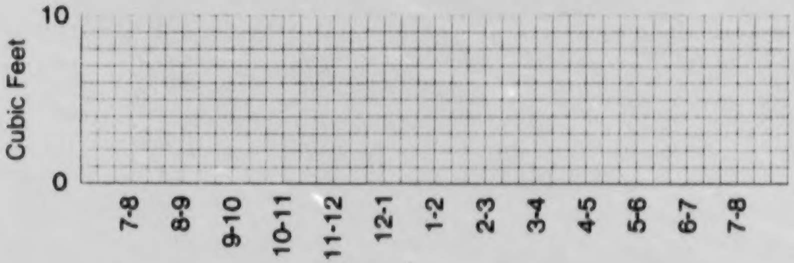
Readings

7 AM	
8 AM	
9 AM	
10 AM	
11 AM	
Noon	
1 PM	
2 PM	
3 PM	
4 PM	
5 PM	
6 PM	
7 PM	
8 PM	

Consumption

7-8	
8-9	
9-10	
10-11	
11-Noon	
Noon-1	
1-2	
2-3	
3-4	
4-5	
5-6	
6-7	
7-8	

Use this form to make a bar graph of your gas consumption that day.



Save this sheet. On a different day of the week, or in a different season, do the activity again and see if your pattern of consumption has changed.

Patterns of Energy Consumption

Note: This lesson involves data on home energy consumption. Before conducting the lesson, be certain that you have informed all parents that you do not require their children to reveal data on their families' use of energy to you or other students. See the remarks on **Protecting Privacy** in the introduction.

Objectives

In addition to its immediate objectives, this lesson initiates student collection of data on their own households' use of energy. This data will be used by the students in later activities in Units Six and Eight.

This lesson contributes to students' understanding of the following concepts:

Energy is measured when it is bought or sold.

There are regular patterns in our use of energy.

Different families tend to show similar patterns.

Format of the Lesson

Discussion of energy use during the day

Discuss electric-week worksheet

Discuss gas-week worksheet

Compare electric week and gas week

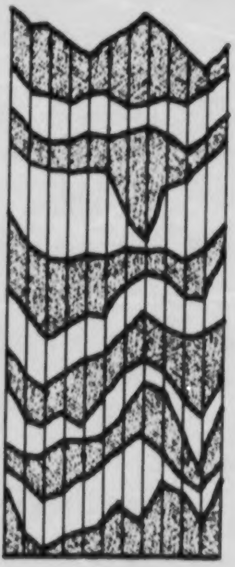
Discuss homework assignment

Materials Needed

completed worksheets from earlier lessons, **Electric Diary: One Day; Electric Diary: One Week; Gas Diary: One Week.**

worksheet **Electric Diary: One Year.** Notice that there is no vertical scale on this graph. This is deliberate, so that it will not be possible to read from the graph how much energy the family used, but only where the peaks and dips were and how steep they were.

Reproducing these worksheets using two papers of contrasting colors can result in a very dramatic display of the regularities of different families' energy consumption (without revealing anybody's consumption). After the students have completed their graphs, have them cut them out along the line representing consumption. Then glue the graphs down on a sheet of poster board, overlapping them like shingles, alternating colors, and lining up the month lines. The overlap should be as great as it can be without covering up any of the peaks and troughs of the graph above it. Similiar displays can be made for the day and the week, though you will have to devise your own forms.



worksheet **Gas Diary: One Year.** Treat in the same way as the Electric Diary above.

Preliminary Discussion

Do we use energy at about the same rate all around the clock, or do we use more at certain periods than others?

On the chalkboard, make a grid of the hours of the day similiar to that on the **Electric Diary: One Day** worksheet.

Ask the students to use their own worksheets and find the hour in which their families used the most electricity, and mark it 1.

Go through the hourly periods on the chalkboard and, by a show of hands, count the number of 1's for each hour and enter on the chalkboard.

What do we notice? That there is considerable clustering. If the one's occurred at random, we would expect them to be more or less spread out. But they aren't. Why? Discuss.

Now find the hour or hours in which you used half as much electricity as you did in the hour you marked 1. Mark that hour ½.

Do the ½'s cluster also?

Discuss what this means in terms of electric energy use. What are some of the implications? (We will take this topic up again in Unit Six.) You might tell this story.

In the early days of television, there was much less choice of programming than there is now. One evening comedy show was particularly popular and most of the people in New York City watched it. One effect of the show was to synchronize people's behavior. Many people waited until the commercial came on to use the bathroom. In those few minutes, then, water ran and toilets flushed all over the city. But the city sewage system was designed to handle a more or less constant flow of water from people flushing their toilets at random. The pipes were big enough to handle the needs of all the people, but not all at once. So the sewage system would back up into low-lying homes in the middle of that comedy show.

Another example is soldiers marching in step. When they come to a bridge, they break step. A bridge is built with many random steps in mind. All the feet coming down at once is a blow that could cause a bridge to collapse.

Examining Energy Use During a Week

Repeat the exercise with the week. Do we use more electricity on some days than others? Why? How do the causes of this pattern differ from the causes of the daily pattern? For example, are weekly patterns due more to custom, like Monday Wash?

Which is more bumpy, the day or the week?

Repeat the exercise with the gas week. Is it more bumpy or less bumpy than electricity usage? Why? Compare the uses of gas and electricity.

Assigning Homework

Pass out the worksheet, **Electric Diary: One Year.**

Observe that this is an activity which, unlike the earlier two, we cannot conveniently do by reading our meters. We have to rely on past records, namely, our utility bills. This means enlisting the cooperation of parents. Some people may not have saved their bills. In that case, many utilities will provide you with a record of your bills for the past year if you call and request it. Of course, a parent would have to do that.

Suggest to the class that the first step in doing this project is to talk to your parent or guardian and get their help. Show them the electric-week and electric-day work you have done; they may be very interested in finding out more about their use of energy; after all, they have to pay for it. As the year goes on, we investigate ways of lowering our energy bills. We can do this more accurately if we know when and what we use energy for.

Tell the class you realize that it may not be possible for everyone to do this exercise, and that a different project will be found for students who cannot obtain the necessary data. (Let this different project be an analysis of the school's use of energy over a year.)

Call the students' attention to the vertical axis of the graph. The space between each pair of horizontal lines represents 10 kilowatt-hours per month. We are not interested in how much electricity you used, but only in how your use of it changed. So you must number these lines yourself. Number the top line with a number in the tens just a bit more than the number of kilowatt-hours you used in the month in which you used the most electricity. Then go down the sheet, numbering all the lines by tens. Notice that the bottom line will NOT be zero.

Demonstrate how this is done on the chalkboard, using a worksheet with a prepared table of sample figures.

Name:

Electric Diary: Year

Dear Parents: As part of our energy-education activities, the students are trying to discover whether the amount of electricity a family uses changes from season to season. They can do this by looking at old utility bills, if you save them, but they will need your help in locating and, perhaps, in reading the bills.

Students record consumption on this sheet, but they do not have to bring it to class if you would prefer they didn't. I would like them to return the accompanying sheet, however, on which they try to locate peaks and dips. Thank you.

You could do this activity by keeping your own records, but it would take a year. So it is better to get this information by looking up old utility bills.

	1975	1976	1977	1978	1979	1980	Five-Year Average
January							
February							
March							
April							
May							
June							
July							
August							
September							
October							
November							
December							

Make a graph of either one particular year's monthly electricity consumption OR find the average monthly consumption over a period of several years and graph that. (Bimonthly if that is how your bills are issued.)

Begin by numbering the horizontal lines as you were shown in class. Number them in pencil. The space between lines represents 10 kilowatt-hours per month. Number the top line with a number ending in 0 which is just a bit bigger than the number of kilowatt-hours you used in the month in which you used the most. Then number the other lines moving down the page. The bottom line will not be zero, but it will be much less than the top line.

Make dots on each of the month lines at the point which represents your family's consumption of energy in that month. Make a heavy ink line through the dots. Then cut off the top part of the sheet, along the edge of the ink line. Finally, cut off the unlined scale with your pencil numbers.

Name:

Gas Diary: Year

Dear Parents: As part of our energy-education activities, the students are trying to discover whether the amount of gas a family uses changes from season to season. They can do this by looking at old utility bills, if you save them, but they will need your help in locating and, perhaps, in reading the bills.

Students record consumption on this sheet, but they do not have to bring it to class if you would prefer they didn't. I would like them to return the accompanying sheet, however, on which they try to locate peaks and dips. Thank you.

You could do this activity by keeping your own records, but it would take a year. So it is better to get this information by looking up old utility bills.

	1975	1976	1977	1978	1979	1980	Five-Year Average
January							
February							
March							
April							
May							
June							
July							
August							
September							
October							
November							
December							

Make a graph of either one particular year's monthly gas consumption OR find the average monthly consumption over a period of several years and graph that. (Bimonthly if that is how your bills are issued.)

Begin by numbering the horizontal lines as you were shown in class. Number them in pencil. The space between lines represents 10 terms. Number the top line with a number ending in 0 which is just a bit bigger than the number of terms you used in the month in which you used the most. Then number the other lines moving down the page. The bottom line will not be zero, but it will be much less than the top line.

Make dots on each of the month lines at the point which represents your family's consumption of energy in that month. Make a heavy ink line through the dots. Then cut off the top part of the sheet, along the edge of the ink line. Finally, cut off the unlined scale with your pencil numbers.

How Many Calories Are There in a Watt-Hour?

Objectives

This lesson contributes to students' understanding of the following concepts:

Electricity can be converted to heat.

A measurement of electrical energy can be converted to a measurement of an equivalent amount of another form of energy.

Format of the Lesson

Discuss electricity to heat conversion

Conduct demonstration

Student calculations of conversion factor

Materials Needed

In this lesson we use electrical energy to heat water. There are several different ways of doing this, requiring different supplies. Before choosing one, read the discussion under Safety, below.

Option one:

electric calorimeter such as Fisher S41755 ($23.55).

Option two, our "homebrew" version:

Thermos® bottle preferably the "Super-Quart" size that holds 36 oz. and takes liner 14QF. About $7.00.

extension cord six-foot molded household. About $1.29.

lamp socket intermediate base, such as Leviton number 199, 59¢ in hardware stores.

bulb 40 watt intermediate base, 40T6½/2, made by Westinghouse and others for use in display cases. About $2.50 at hardware stores. The intermediate base is one step smaller than the household "medium" size and one size larger than the candelabra base. This size is small enough for the socket to get through the neck of the Thermos bottle. If you have many low voltage isolated outlets, you may wish to use a 12 volt bulb instead. See below.

silicone glue-sealer such as General Electric Catalog number GE2562-01DP. ($3.19 for 83mL, much more than you need). Available in hardware stores.

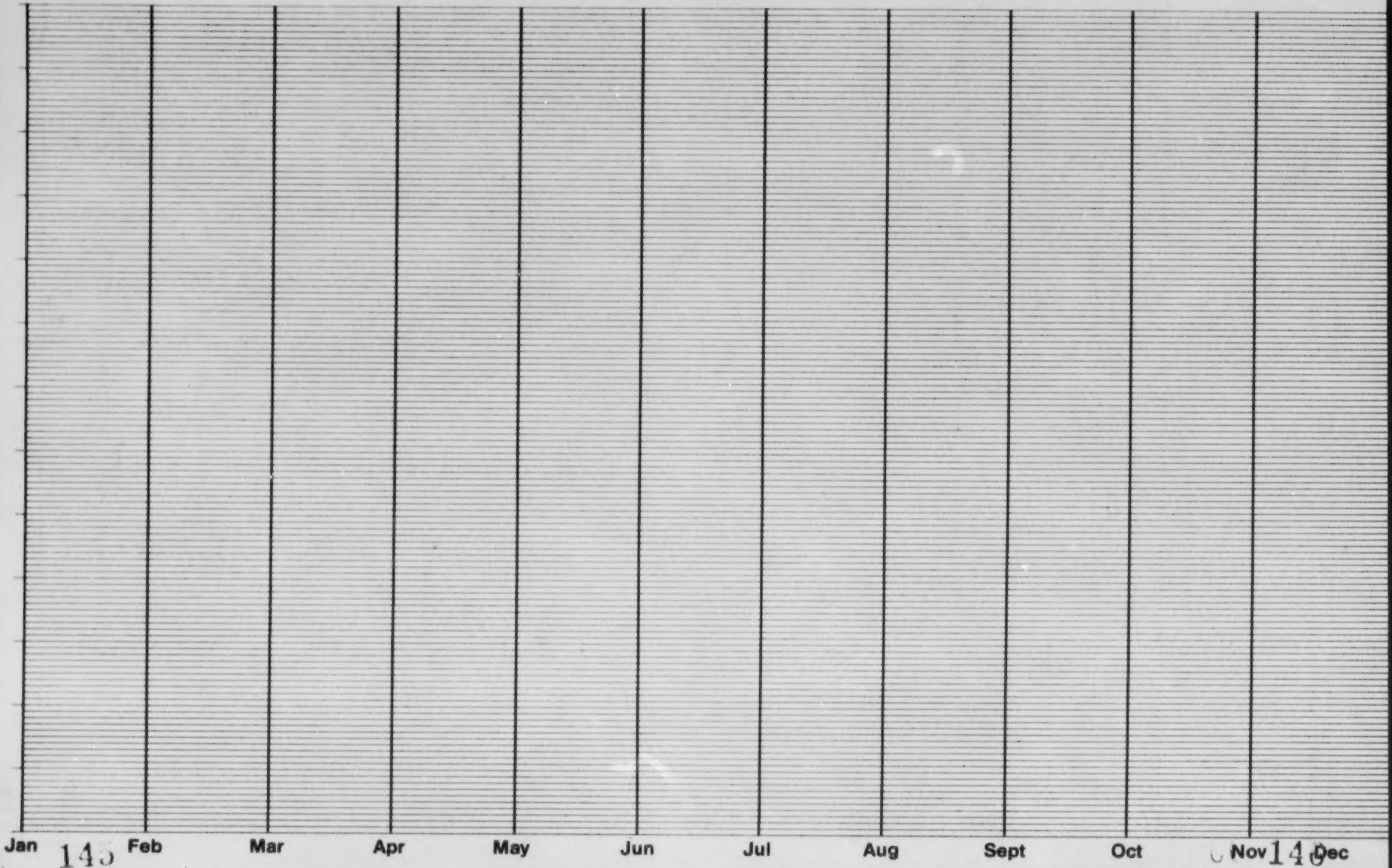
Option three, without the Thermos bottle:

immersion heater one-cup type

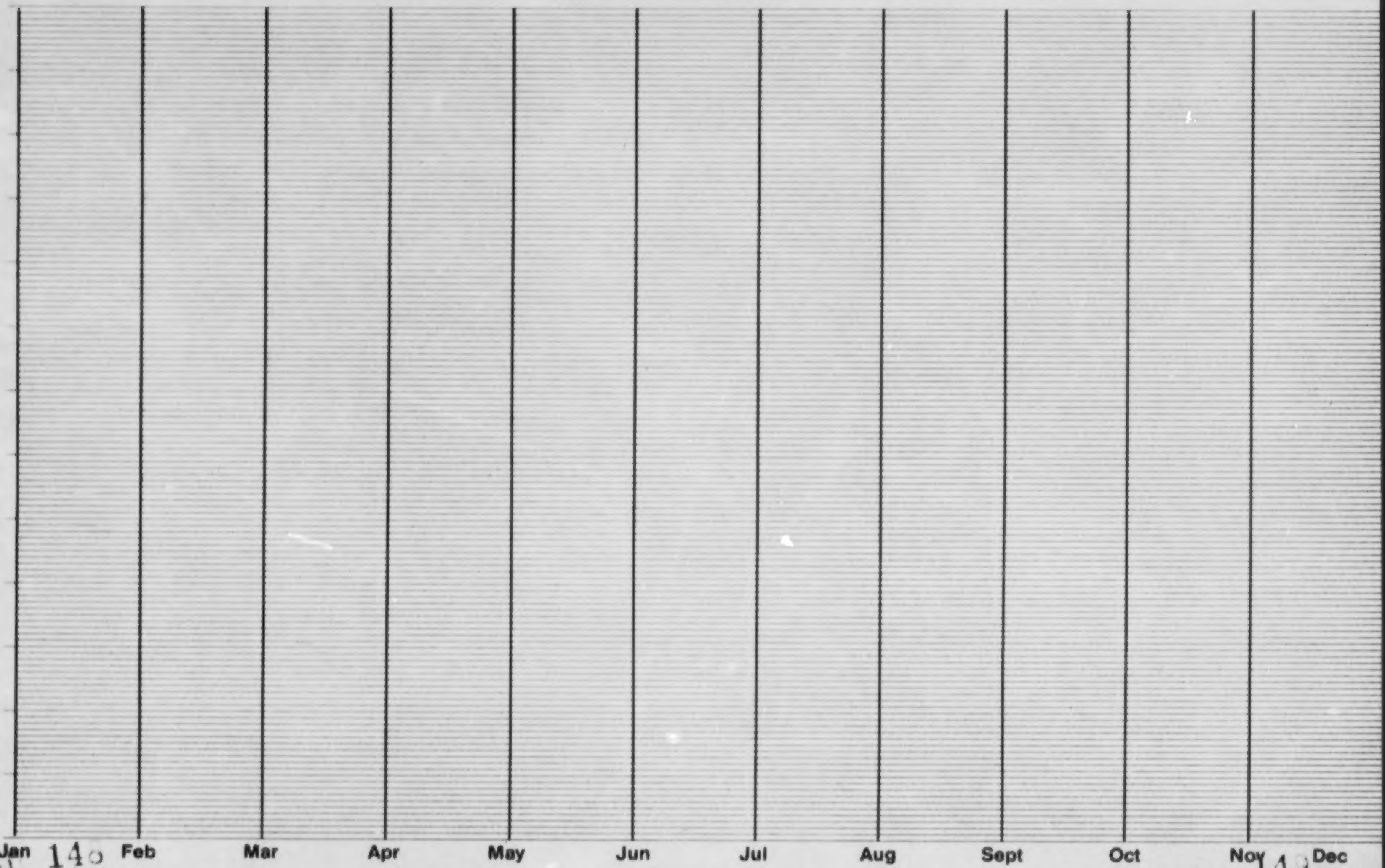
OR

aquarium heater preferably the type used with a separate thermostat, just a tube containing a heating element packed in sand.

The Shape of My Family's Consumption of Electricity Over a Year



The Shape of My Family's Consumption of Gas Over a Year



Teacher Background

In this investigation, electricity is used to heat a measured mass of water, preferably in a Thermos bottle. Knowing the change in temperature of the water and its mass, we can calculate how many calories of energy (in the form of heat) were added to the water. Knowing the input of electrical energy in watts, and the time the heater was on, we can calculate how many watt-hours of energy (in the form of electricity) were added to the water. Of course, we are talking about the same energy (changing from one form to another), and so the measurements must be equivalent. Comparing them tells us how many calories is equivalent to a watt-hour.

Safety

Combining water and electricity obviously raises a question of safety.

One way of minimizing hazard is to use heaters designed for water, such as a one-cup immersion heater or an aquarium heater. Unfortunately, it is difficult to get good results with these because of the trouble it takes to insulate the water containers they will fit, and because they have a lot of thermal inertia themselves.

The homemade substitute, whose construction is described below, consists of a 40 watt waterproofed bulb run on line voltage. Note that there is **NO** exposed conductor anywhere in the finished setup if the plastic-walled Thermos specified is used. Still, we suggest that if this is the apparatus you choose, the investigation be done as a teacher demonstration.

A third alternative, if you have an isolated low voltage power supply, is to use a low voltage lamp such as a 12 volt automobile bulb. Since bayonet sockets are hard to find, you will probably have to solder wires directly to the bulb; otherwise, construction would resemble that described below. Incidentally, the demonstration does not work well with 110 volt 7½ watt bulbs, the size used for Christmas trees, and you would need an automotive bulb that drew around 40 watts as well.

Constructing the Heater

This should be done by an adult, not by students.

Cut the molded socket (not the plug!) from one end of the extension cord and throw it away. Strip about 1 cm of insulation from the two wires. Twist the strands of each wire together and bend the uninsulated portion of each into a U-shape.

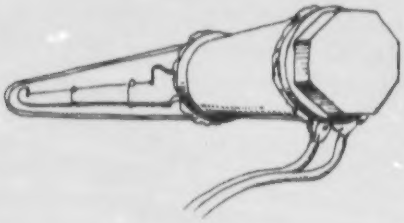
Unscrew the cap at the end of the socket. Two metal pins will be seen. Place one U over each pin. Be sure there are no loose strands of wire connecting the two pins. Screw the cap back on. (Ordinarily, these pins are used to penetrate the insulation of the wire. The wire used in household extension cords is not the right gauge or type for that system to work reliably.)

Clean all grease from the socket and the glass near the base of the light bulb. Screw the 40 watt light bulb into the socket, not too tightly. Plug in the assembly to confirm that the wires are making good contact with the pins.

Trim only the tip from the nozzle that comes with the silicone sealer, so that only a small hole shows. Put the nozzle on the tube. Pushing a bead of sealer **ahead** of the nozzle, squirt sealer into the space between the bulb and socket. Be generous. Do not pull the nozzle away from the sealer you've extruded; push towards it! Go all the way around the socket. Then unscrew the bulb one quarter turn and screw it back in again, fairly tight.

Squirt into the holes where wire is supposed to enter and leave the socket, as much as will go in. Be especially careful to go all around the wires. Then run a bead of sealer around the joint between the screw-on cap and the rest of the socket.

The entire construction, start to finish, takes about five minutes. Replace the cap on the sealer tube. Let the sealer dry for 24 hours, then test the bulb by immersing it in water in the Thermos and plugging it in. Always put the bulb in water before turning it on; dunking a hot bulb could shatter the glass.



Converting Electricity to Heat

Begin the lesson by discussing the following sequence of questions:

Do you know any way of converting electricity to heat?

Do you know a way of measuring a quantity of heat? (ANS: Description of ways of measuring calories or Btu's.)

Do you know a way of measuring a quantity of electrical energy? (ANS: Kilowatt-hours.)

If we can convert some energy in the form of electricity into the form of heat, then a measurement of the amount of energy in kilowatt-hours must be equivalent to a measurement of the same energy in calories. There must be a conversion factor to convert kilowatt-hours to calories, just as there is a conversion factor to convert inches to centimeters.

How can we find out how many calories there are in a kilowatt-hour?

Entertain proposals from the class.

Demonstration

You may want to give students the activity sheet to help them follow the demonstration; in any case, provide the worksheet and let students do the calculations. (If you have the necessary equipment, you may want students to do the activity in groups.)

Post-Activity Discussion

The "correct" value for the number of calories in a watt-hour is 860.4. You may want to share this value with the class and discuss what the sources of inaccuracy in our experiment might be. For example, was water the only thing heated? (As a general rule, other substances, like glass and plastic, have specific heats very different from that of water.) Could energy escape from the Thermos? How accurate were our measurements? Could we design a more precise experiment?

Summarize for the class that, since energy is interchangeable from one form to another, any measurement is also interchangeable. We will do this as we learn ways of measuring other forms of energy.

Converting Electricity to Heat

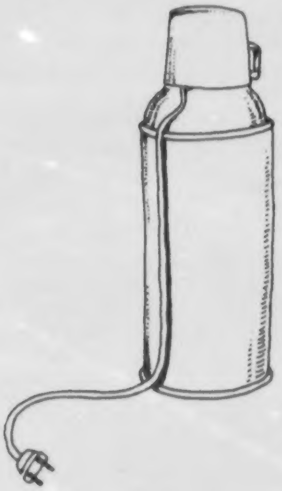
You know that electrical energy can be converted to heat. Therefore, there must be a way of finding how many calories are equivalent to one watt-hour of electricity. In this investigation, you will try to do that.

To do this experiment, you will need:

- ☐ an all-plastic Thermos bottle
- ☐ a thermometer graduated in degrees Celsius
- ☐ a graduated cylinder or volumetric flask
- ☐ a clock with a second hand or a digital stop watch
- ☐ an electrical power supply approved by your teacher
- ☐ a waterproofed low-voltage light bulb and socket, or electric heater, supplied by your teacher

voltmeter and ammeter; or multimeter (optional)

Do you have everything you need?



Procedure

Step One: Measure 800 milliliters of water and place it in the Thermos bottle. What is the mass of one milliliter of water? Make a record of the mass of the water you put in the bottle.

Step Two: Examine the light bulb and make a record of its marked wattage. Insert the light bulb into the Thermos. **DO NOT PLUG IT IN YET!** Be sure it is as far down in the bottle as possible, completely covered with water. Measure the temperature of the water and make a record of it.

Step Three: Put the cap on the bottle, gently force-fitting it (you won't be able to screw it on because of the wire). Put the cup over that.

Step Four: Connect the light bulb to the electrical supply and begin timing. Make a record of the time, to the nearest second, when you plugged the bulb in. Leave the bulb on for 15 minutes, to the nearest second.

Step Five: If you have an electric meter, measure and record the voltage and amperage of the current flowing into the bulb while the bulb is on.

Step Six: At the end of 15 minutes, unplug the bulb. Leave it in the water. Measure the temperature of the water and make a record of the reading.

Step Seven: Put away the materials.

Step Eight: Calculate a factor for converting watt-hours to calories. You may use the worksheet provided by your teacher.

How Many Calories in a Watt-Hour?

A. Calculate how much electrical energy went into the Thermos.

volts X amps = watts　　　watts X minutes = watt-minutes

__________ volts

__________ amps

(If you did not use a meter, enter wattage of bulb here) __________ watts

X __________ 15 minutes

__________ watt-minutes

Can you change that to watt-hours? __________ watt-hours

B. Calculate the increase in heat energy in the Thermos.

(change in temperature in degrees Celsius) X (mass of water in grams) = calories

end temperature __________ °C

beginning temperature – __________ °C

change in temperature __________ °C

mass of water heated X __________ grams

calories __________ calories

C. Calculate the conversion factor.

So __________ calories = __________ watt-hours

or __________ calories = 1 watt-hour

Some questions

1. Why did we use a Thermos bottle? __________

____

____

2. Did we heat anything besides water? How will that affect our accuracy? __________

____

____

First-Law Efficiency

Objectives

This lesson contributes to the students' understanding of the following concepts:

Energy can be measured.

Energy measurements can be converted from one type of unit to another.

When we use energy, we are usually unable to convert all the energy we put in into the form we want.

The ratio of the energy we get out in the form we want it, to the energy we put in, is called (first-law) efficiency.

In evaluating energy use, we must look at all parts of the system.

Format of the Lesson

Review energy use as converting one form to another

Review energy measurement and conversion factors

Idea of efficiency

Demonstration

Student calculations

Optional: comparison with second pot

Review demonstration system

Optional: Discuss variables

Optional: Discuss sources of error

Materials Needed

water

thermometer graduated in degrees Celsius.

graduated cylinder to measure cubic centimeters of water. If you have no graduated cylinder you may use an ordinary cup measure; one cup equals about 236.5 milliliters. Or jars can be calibrated to hold one liter, marking the level on tape on the side of the jar.

sauce pan or pot, about two-liter size. Ideally, the investigation should be done twice, once with a pot with a heavy flat bottom, like a Farberware pot, and once with a thin aluminum pot with a dinged and beaten up bottom.

electric hot plate you must know how many watts or amps this hot plate draws.

clock or watch with a sweep second hand.

activity sheet **How Efficient Is an Electric Hot Plate in Heating Water?** One is needed for each student actually doing the investigation. If it is done as a teacher demonstration, activity sheets are not necessary.

worksheet **Hot Plate Efficiency Calculations.** One per student.

Using Energy Usually Involves Converting It from One Form to Another.

Discuss some household uses of energy in terms of energy flows. Ask such questions as,

"Tell me something you use energy for in your household."

"What kind of energy do you start with?"

"What kind of energy do you end up with?"

Establish that there is always an energy input and an energy output.

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Review Measurement and Conversion

Point out that in all the examples the students have given they could measure the energy they started with. For example, they have learned how to measure electric energy.

Point out that they can also measure the energy that they got out in the form in which they wanted it. For example, we can measure heat energy, mechanical energy, and so forth.

Efficiency

We have a special name for the ratio

$\frac{\text{energy out}}{\text{energy in.}}$ We call it efficiency.

This ratio can be expressed as a percentage.

Discuss Demonstration

Propose that we do an investigation comparing the amount of energy we put in with the amount of energy we get out in the form we want. We will do this by using an electric hot plate* to heat some water.

"What kind of energy goes into an electric hot plate?" (ANS: Electricity.)

"How can you measure the amount of energy being used by a hot plate?" (ANS: Measure kWh consumed.)

"What form of energy are we trying to get?" (ANS: Heat in the water.)

"What units can we conveniently use to measure heat in the water?" (ANS: Btu's or calories.)

"'Is it possible to convert the kilowatt-hours to calories?" (ANS: Yes, if we know the conversion factor.)

Ask students to make a wild guess at what the efficiency of the hot plate and pot will be.

Pass out the activity sheets, if students are to perform the investigation, and calculation work sheets.

Assign students to the following jobs:

Water Measurer

Time Measurer

Temperature Measurer

If you have more than one hot plate (and enough electricity to run them simultaneously) this investigation can be done by several groups of students. Comparing results (particularly if identical hot plates and pans are used) provides a valuable opportunity to discuss sources of experimental error.

If you have one hot plate and one pan and must do the investigation as a demonstration, have the students who are making the measurements write the figures they obtain on the chalkboard. The rest of the students may enter the data on their worksheets and calculate individually.

Directions for the investigation are given on the activity sheet.

---

*Apparently the first to think of using the hot plate to demonstrate efficiency were Mark Terry and Paul Witt. Such an experiment is described in their excellent book, **Energy and Order, A High School Teaching Sequence** (San Francisco: Friends of the Earth, 1976).

Some Pitfalls

Heating 1 liter of water on a 1000 watt hot plate should take five to seven minutes.

Don't let the water boil. If the water actually comes to a boil, the calorie measurement will no longer be valid, since energy used in changing 100°C water to 100°C steam does not increase its temperature. (But a student might want to try determining how many calories it takes to convert 1 gram of 100° water to steam. No additional apparatus is needed.)

Instructions on the worksheet call for turning on the hot plate before putting the pot on it. This allows the hot plate to reach an equilibrium temperature with the room. An alternate procedure is to put the pan of water on the hot plate before turning it on. In that case part of the electrical energy going into the hot plate during the measured period is being used to heat the hot plate itself. The disadvantage of that procedure is that to replicate the experiment, you must let the hot plate cool to room temperature, and that takes a long time.

Experimenting with Different Pots

If time permits, it is very instructive to repeat the investigation using different pots, to see if efficiency differs from pot to pot. In fact, it will. To ensure that a striking difference will exist, use one pot with a strong, flat bottom, like a Farberware pot, and another with a dented and beaten up bottom, like a battered thin-gauge aluminum pot. The efficiency of the hot plate-pot system is very sensitive to the contact between the pot and heating element, and thin aluminum pots with dented bottoms conform very poorly to the surface of the electric hot plate.

To save time, start measuring water for the second pot as soon as the first pot is on the hot plate. Provide additional worksheets.

After the Investigation

Review, step by step, what has been done:

How did we measure the energy in?

How did we measure the energy out?

Did we get as much energy out as we put in?

What happened to the missing energy? Where did it go?

Is the percentage we arrived at the efficiency of the pot, or the efficiency of the hot plate? (This is easier to discuss if you've tested several pots.)

Would the pot have the same efficiency on a gas stove? (ANS: Try it and find out.)

What we have obtained is the efficiency of this particular pot-hot plate combination, or system; not the efficiency of the pot itself.

Variables (optional)

Many classes are capable of some very stimulating speculation on what the variables in this investigation are, especially if they have compared different pots. A good starter question is why the efficiency of the pots differed. Ask the class to devise an experiment to test each hypothesis proposed.

Although it is best if students suggest the variables, here are some leading questions. (You might think of more.) In all the following questions, by "does it matter," we mean, "Would you get different results if you repeated the experiment and changed only this factor?"

Does it matter how long we heat the pot?

Does it matter what temperature the water is to begin with?

Does it matter what the pot is made of?

Does it matter what shape the pot is?

A key concept in understanding the role of many of these variables is that the rate of heat flow between two bodies depends on the difference in their temperatures. Starting with water at 30°C will not give the same results as starting with 20°C water because the rate of heat flow from pot to room will be greater.

Sources of Error (optional)

Even if all variables are controlled, we would get a range of results. (This will have happened if you were able to do the investigation in groups with identical pans and hot plates, or repeated it.) Why does this happen?

What measurements go into our calculations?

How sure can we be of each of these measurements? Volume of water, for example. How many milliliters off do you think you might have been?

Temperature. With what accuracy can our thermometers be read? (Try it — have several students read the same pot of water and record their measurements separately.)

Time. How many seconds error might have been possible in reading the clock, or in putting on or taking off the pot?

How accurate is the wattage or amperage rating of the hot plate?

How does wattage depend on the line voltage? Is our line voltage what the manufacturer expected? Does it change?

How do these sources of error compound one another?

Homework Assignment

An optional homework assignment, which requires only kitchen utensils, is provided on the opposite page for possible reproduction.

Projects for Independent Investigation

1. In which type of stove is the efficiency of heating water least sensitive to differences in pots: an electric stove, or a gas stove? Substantiate your opinion with experimental measurements.
2. What differences does a cover make in increasing the efficiency of a pot used to heat water?
3. Design an energy-efficient pot.
4. Who was Benjamin Thompson (Count Rumford)? Report to the class on Rumford's improvements in fireplaces. See if you can find his suggestions for improving stoves and pots.

Homework Assignment

In this experiment you will try to determine which is the most efficient pot for heating water on your home stove. The amount of water to be heated is exactly two cups.

1. Choose two pots you think might be the most efficient ones on one particular burner on your stove.
2. Put two cups of water in each of the two pots. Make sure the water is at the same temperature. If you think that the water that came out of the faucet first is warmer than the water that came out later, let the pots of water sit until they reach room temperature.
3. We will estimate how much energy is being used to heat the water by measuring the length of time the pot is on the stove. We will estimate temperature by removing the pot at the moment at which it begins to boil. Boiling is not the time at which small bubbles appear on the sides of the pot. By boiling we mean a full, rolling boil.
4. Turn on the gas or electric burner. Note the time and put one of the pots on the burner. As soon as it comes to a boil note the time and take if off. Immediately subtract to find how many seconds the pot was on the burner. Write the number in the space below. Now do the same thing with pot number two.

seconds for pot #1 to come to a boil

____________________ seconds.

seconds for pot #2 to come to a boil

____________________ seconds.

5. Was one pot more efficient than the other? Can you think of any reasons why?

Hot Plate Efficiency Calculations

1. Calculate the number of calories added to the water.

One calorie is the amount of energy needed to raise the temperature of one gram of water one degree Celsius.

calories = (rise in temperature in degrees Celsius) x (grams of water)

To find the rise in temperature:

ending temperature (in degrees Celsius)	°C
beginning temperature	– °C
rise in temperature	°C

To find the number of calories added to the water:

grams of water heated	X grams
calories added to water	calories

2. Calculate the number of calories supplied to the electric hot plate.

wattage of electric hot plate	watts
minutes pot was on hot plate	X minutes

watt-minutes = watts x minutes

energy delivered to hot plate	watt-minutes

Which has more energy,a watt-minute or a watt-hour?

Knowing there are 60 minutes in an hour, change the watt-minutes to watt-hours.	watt-hours
One watt-hour is equivalent to about 860.4 calories,	X 860.4
so the total energy input to the hot plate was	calories

3. Calculate the efficiency of your pot plus hot plate combination.

$$\frac{\text{energy out in desired form (hot water)}}{\text{energy in (as electricity)}} =$$

$$\frac{\text{\_\_\_\_\_\_ calories}}{\text{\_\_\_\_\_\_ calories}} \times 100\% = \text{\_\_\_\_\_\_ }\%$$

How Efficient Is an Electric Hot Plate in Heating Water?

To find out, we would have to measure the energy input (the electricity supplied to the hot plate) and the energy output in the form we wanted (heat added to the water). Then we could compare the two. In this experiment, we will make these measurements and then see what part of the energy in came out the way we wanted it.

Your teacher may assign one student to measure the mass of water, one to measure time, and one to measure temperature. Or you may be asked to do this experiment all by yourself.

To do the experiment, you need:

☐ an electric hot plate

☐ a pot

☐ a graduated cylinder or other means of measuring milliliters of water

☐ thermometer graduated in degrees Celsius

☐ watch or clock with a sweep second hand

Do you have all the things you need?

Procedure

Read all the directions before starting to do the experiment.

Step One: Examine the hot plate. How many watts is it? Make a note of the wattage. Turn on the hot plate and let it sit for two minutes while you get the pot ready. Allowing the hot plate to warm up lets it get as hot as it's going to. When the hot plate has just been turned on, most of the energy goes into warming up the hot plate itself.

Be sure the hot plate is in a safe location where people won't accidentally burn themselves.

Step Two: Measure some room-temperature water and put it in the pan. Fill the pan more than half full. Make a note of how many milliliters of water you put in the pot.

Do you remember that one milliliter of water has a mass of one gram? How many grams of water are in the pot?

Step Three: Measure the temperature of the water in the pot, in degrees Celsius. Make a note of the temperature. It should be room temperature.

Step Four: Decide on a time when you will put the pot on the hot plate. Make a note of the time (say, ten thirty-one and twenty seconds). At exactly that time, put the pot on the hot plate.

Now decide on a time when you will take the pot off. Let it be a whole number of minutes. If you used a liter of water, five minutes is a good length of time. So if you put the pot on at ten thirty-one and twenty seconds, you could decide to take it off at ten thirty-six and twenty seconds.

DO NOT LET THE WATER COME TO A BOIL.

If the water comes to a boil, some of the electrical energy will be used to change water into steam, and will not raise the temperature of the water. If your water comes to a boil, stop and discard the boiling water in a safe manner (call your teacher). Then go back to Step Two and start over, but this time don't heat the water for such a long time.

Step Five: Take the pot off at the right time and immediately measure the temperature and how many minutes the pot was heated.

Step Six: Unless your teacher tells you not to, unplug the hot plate. Put the plate and the hot water in a safe location where no one will accidentally touch them.

Incandescent Versus Fluorescent Efficiency

Objectives

This lesson contributes to the students' understanding of the following idea:

A difference in efficiency can result in a substantial decrease in costs.

Format of the Lesson

Review concept of efficiency

Compare wattage and light output of two lights

Point out ballast losses

Sample survey of lighting in the classroom

Materials Needed

incandescent light bulb fixture it is convenient if this is mounted on a board. Ask for a keyless porcelain lampholder, without pull chain or convenience outlet, such as Paulding Catalog #1625. About $1.50. Or you can clamp a trouble light in a ring stand. In any case, a bare bulb, without shade or reflector, is needed.

incandescent light bulb see below for choice of wattage.

fluorescent bulb and fixture with screws removed so that the top can be lifted to show the ballast. The wattage should approximately match that of the incandescent. Here are some pairings:

A 40-watt incandescent with a 40-watt (47¼") fluorescent. Forty watts is a realistic size for household incandescents, and this is the brightest, easiest-to-see combination. But single-tube, 40-watt fixtures are hard to find, and cost about $20 when you do.

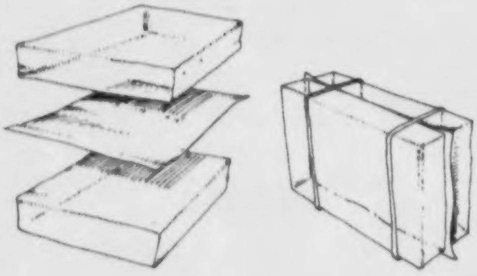
A 25-watt incandescent and a 22-watt "circiline" fluorescent. The fluorescent is available as part of a package to screw into existing lamp sockets (e.g., Star Lite Model No. 1000-2B, about $12.50). If you use this, tilt the bulb so that both sides of the ring are visible from the position of the photometer.

A 15-watt incandescent and a 15-watt fluorescent. The advantage here is that the 15-watt fluorescent is readily available in such configurations as Westinghouse's "Luma-Stick" (plastic fixture and lamp for about $17.25). It is hard to show the ballast on such fixtures, however, and the light is fairly dim if you cannot darken your room.

photographer's light meter an incident light meter that reads in footcandles is preferable (the kind with a white plastic disk or hemisphere). If the only meter available is a reflection meter, take readings off a piece of light gray paper. Ask the meter's owner to explain the technique.

OR

paraffin photometer which can be made by cutting a ¼-pound block of paraffin in two, separating the two pieces with a sheet of aluminum foil, and holding the assembly together with two rubber bands.



meterstick

overhead transparency of survey form

Demonstration

Review the concept of efficiency as a ratio of the energy we get out in the form we want it to the energy we put in. Ask the class what form of energy we want from an electric light. What form of energy do we put in?

Display two lights, one 40-watt incandescent and one 40-watt fluorescent. Point out that each is marked 40 watts. Darken the room and plug them in. Which appears to put out the most light?

Tell the class we will try to get a more exact measure of the relative brightness of the two lights.

If you are using a light meter, ask a group of students to test the light outputs with the light meter.

If no light meter is available, the difference in brightness can be compared through the following activity.

Place the incandescent light on one end of a long table. Exactly one meter from it, put the paraffin photometer, with one side facing the light. Place the fluorescent lamp on the other side of the photometer, a meter away from the photometer.

Have students observe the edge of the photometer. The incandescent light will look yellower than the fluorescent; try to ignore this. It may help to cut a small hole in a piece of black construction paper and put it over the photometer. Are the two sides of the photometer equally bright? (ANS: No, the fluorescent side is brighter.)

We can slide the fluorescent farther away until the two sides are the same brightness, and this gives us a rough way of estimating the relative brightness of the two lights.

Teacher Background

Light falls off as the square of the distance. The following table, which is simply squares, can be used to compare brightness:

If the incandescent is at one meter and the fluorescent at the given distance, then it will be the given multiple brighter.

1.1 meters = 1.2 times brighter
1.2 meters = 1.4 times brighter
1.3 meters = 1.7 times brighter
1.4 meters = 2 times brighter
1.5 meters = 2.25 times brighter
1.6 meters = 2.6 times brighter
1.7 meters = 2.9 times brighter
1.8 meters = 3.2 times brighter
1.9 meters = 3.6 times brighter
2 meters = 4 times brighter

So we can conclude that, watt for watt, we do get more light from the fluorescent.

The Ballast

Tell the class that there is another factor we must be aware of. Unlike an incandescent bulb, the bulb wattage of a fluorescent does not tell us the entire electrical consumption of the light. When a fluorescent is operating, there is an arc inside the tube that is almost a short circuit. To keep too many amps from flowing through the arc, which would burn out the tube and all the fuses, fluorescent lamps include a device called a ballast. The ballast limits the number of amperes flowing through the tube.

With the fluorescent unplugged, remove the cover and point out the black box that is the ballast. Unfortunately, the ballast also consumes energy. Invite students to feel it. It will be hot. It converted some of the electricity flowing through it to heat.

So, in calculating the power consumed by fluorescents, we shouldn't use lamp wattage, but lamp-plus-ballast wattage.

Surveying a Room

Pass out the survey form and ask the students, as homework, to see how much difference more efficient lights would make in some particular room. They can choose the room; any room that has some incandescent lighting (the more, the better). To show how it's done, do a practice run in class.

If your classroom has no incandescent lights, consider making a class data-gathering visit to an area of the school where there are some.

After collecting data, return to the class to analyze them. You may find an overhead transparency of the form useful in showing how to fill it out.

The form is mostly self-evident, though it is necessary to walk the students through an example so that they understand how to use it. One area of potential confusion is the "hours per week" column. We find this figure by estimating the number of hours each individual bulb was on and then adding to get a total for all bulbs of that wattage. Be sure students do not think that they can find "hours per week" by multiplying the number of bulbs by some average figure. Thought and scratch paper are necessary.

Projects for Independent Investigation

1. Most light bulbs are now sold with their light output in lumens marked on the side of the package. In the supermarket, make a list of the wattage and lumens of as many bulbs as you can find. Can you find a relationship between wattage and efficiency (lumens per watt)?
2. Some incandescent light bulbs are made to last longer than others. Frequently, the expected hours of life are marked on the package. Collect data in the same way as for Project 1. Can you find any relationship between how long a bulb is expected to last and its efficiency?
3. Fluorescents come in different colors, like warm white, deluxe warm white, daylight, cool white, and so forth. Are bulbs of one color more efficient than others? How could you demonstrate this experimentally?

Lighting Efficiency Survey

Does using more efficient devices really make a difference? In this activity, you will survey the electric lighting now being used in a particular place, such as your schoolroom, bedroom, the gymnasium, or any other place where incandescent lighting is being used. List all the incandescent lights by wattage, using one line per wattage, and tell how many of them there are. Estimate how many hours each bulb burns in a week and find the total hours for all bulbs of that size. Multiply by watts to find the kilowatt-hours consumed each week by each wattage.

Many rooms are overlit; in some there is not enough light. Do not be concerned about that now. We are only interested in finding out what we could save by using a more efficient light source.

Table 1. Incandescent Lights

Watt rating	Number of bulbs	Hours per week	kWh per week
1			
2			
3			
4			
5			
6			

Total kilowatt-hours per week = ________ kWh

How much does the electricity to run these lights cost per kWh? $________ kWh

Total Cost of Light

$________ per kWh × ________ kWh = $________

Now lets replace the incandescents with fluorescents. Here are some *approximate* practical equivalents. The lumen is a unit that measures light.

Incandescent wattage	Light output*	Fluorescent lamp wattage	Lamp+ballast wattage	Light output*
25-watt	235 lumens	6-watt	8-watts	230 lumens
40-watt	455 lumens	13-watt	19 watts	655 lumens
60-watt	870 lumens	20-watt	26 watts	1110 lumens
100-watt	1750 lumens	40-watt (circiline)	56 watts	2055 lumens
150-watt	2880 lumens	40-watt rapid start	52 watts	2779 lumens
200-watt	4010 lumens	two 40-watt rapid start	94 watts	5280 lumens

*Both incandescent and fluorescent lamps dim with age. The output of the incandescents is given for brand-new bulbs; for the fluorescents, when they have passed 40% of their rated average life.

Table 2. Fluorescent Replacements

How many fluorescents of what wattages would be needed to replace the incandescent lights in Table 1? For each line of Table 1, make a line in this table.

Fluorescent lamp wattage	Lamp+ballast wattage	Hours per week	kWh per week
1			
2			
3			
4			
5			
6			

Total new kilowatt-hours per week = ______ kWh

Kilowatt-Hours Saved

kWh consumed by incandescents replaced = ______ kWh

kWh consumed by fluorescents added = – ______ kWh

kWh saved ______ kWh

times cost of a kilowatt-hour x $ ______

utility charges saved in one week = $ ______

utility charges saved per year = $ ______

Question: In what room of the school would replacement of incandescents by fluorescents save the most utility charges? In what room of your home?

Systems Efficiency

Objectives

This lesson contributes to the students' understanding of the following concepts:

To judge the efficiency with which a machine or process uses energy, we must examine the efficiency of the system of which that machine or process is a part.

Format of the Lesson

Preliminary discussion

Completion of water heater worksheet

Discussion of results on the water heater worksheet

Presentation of electrical generating system

Explanation of calculation of system efficiences

Calculation of electrical system efficiency

Comparison of electric and gas water heaters

Final discussion and summary

Materials Needed

worksheets **Estimate of Where the Annual Energy Input to Residential Water Heaters Goes,** one per student.

overhead transparency **Electrical System** (optional).

Preliminary Discussion

Review the previous activity when the efficiency of the hot plate pot system was calculated. Review the definition of efficiency.

Review any independent investigations or homework assignments completed by students involving efficiency of pots, lights, etc.

Announce that we will now compare some efficiencies of another way of heating water, namely home water heaters.

Distribute the worksheet on water heater efficiencies.

Completing the Worksheet

Help students complete the calculations indicated on the worksheet.

Discuss which type of water heater seems to be most efficient in converting its energy input into heat in water.

Ask where the electrical water heater got its energy. There may be a number of credible answers, for example, from hydroelectric plants, from coal-fired boilers, and so forth. Tell the students that for the sake of comparison we will examine the case in which the electricity came from the power plant fired by natural gas (about 18% of the electricity generated in the United States in 1979 did come from natural gas). This way we are comparing two different ways of using the same energy source.

From Natural Gas to Electricity at the Wall Receptacle

Ask the students what must be done to make electricity from natural gas. On the chalkboard create a diagram of the electrical generating system similar to that shown in the drawing on the next page, or use an overhead transparency. You will need to give students some of the information.

Point out that each of the parts of this system has its own efficiency, just as the water heater has a particular efficiency. For example, the boiler of the power plant converts the chemical energy of natural gas to heat energy in steam. Of course, some of the heat will not end up in the steam but will be lost in heating the equipment itself, and some will go up the smokestack as heat in the flue gases. Because of this a typical boiler has an efficiency of about 77%.

Modern power plant steam turbines typically have an efficiency of about 45%.

The electrical generators connected to the steam turbine change the mechanical energy into electricity. Large generators like these have an efficiency of about 99%. Review that this means that only 99% of the mechanical energy we put in comes out as electrical energy; 1% escapes as heat.

Perhaps the hardest part of the system to think of in terms of efficiency is the transmission system itself, which includes transformers, wires, switches, and so forth. Whenever electricity flows through a wire the wire is heated, because all wires have some resistance. Because of heating wires, transformers, and so forth we don't get out of an electrical transmission system all the energy that we put into it. A 300-mile transmission system will have an efficiency of approximately 91%.

So, our problem now is, if we know the efficiencies of each of the components, how can we calculate the efficiency of the system? Or to say it another way, how much of the energy we put into the boiler will we get out of the water heater?

Calculating System Efficiencies

Imagine a system that has only two components. Component A has an efficiency of 50% and component B has an efficiency of 20%. Make a drawing like this on the chalkboard.

$$\overset{50\%}{\boxed{A}} \qquad\qquad \overset{20\%}{\boxed{B}}$$

Suppose we put in 100 calories. What will we get out of A? (ANS: 50% of 100 calories = 50 calories.)

$$\text{100 calories} \longrightarrow \overset{50\%}{\boxed{A}} \longrightarrow \text{50 calories} \longrightarrow \overset{20\%}{\boxed{B}}$$

So, what will we be putting into component B? (ANS: 50 calories.) What will we get out of component B? (ANS: 20% of 50 calories = 10 calories.)

$$\text{100 calories} \longrightarrow \overset{50\%}{\boxed{A}} \longrightarrow \text{50 calories} \longrightarrow \overset{20\%}{\boxed{B}} \longrightarrow \text{10 calories}$$

What is the efficiency of the whole system?

Answer: $\frac{\text{energy out}}{\text{energy in}} = \frac{\text{10 calories}}{\text{100 calories}} = 10\%$

Is there a way of calculating the system efficiency without actually calculating what's left after each step? Some students may perceive there is: if not, point out that multiplying the efficiences of all components gives the system efficiency: i.e.,

$$50\% \times 20\% = 10\%$$

Back to the Water Heaters

Now let's look at the water heaters again. The system efficiency of the electric water heater is:

$$\underset{\text{boiler}}{77\%} \times \underset{\text{turbine}}{45\%} \times \underset{\text{generator}}{99\%} \times \underset{\text{transmission}}{91\%} \times \underset{\text{water heater}}{79\%} = 25\%$$

Final Discussion

At first, at 79% compared to 46%, the electric water heater looked much more efficient than the gas water heater. Now which looks more efficient?

The smart way to evaluate energy is to look at the whole system, not just a piece of it.

Answers to Homework

I. Here are some possibilities, many of which one would not expect the students to be aware of. (They are only asked to think of two or three.) Also, this list is not exhaustive. In deciding whether a proposed component is actually a part of the system, ask yourself whether it could have an efficiency. Could more energy go in than came out in the desired form?

1. Fusion in sun, transmission as radiation, photosynthesis in plants, digestion in cow, burning in stove-pot system.
2. Fusion in sun, photosynthesis in plants, geological processes, petroleum extraction, petroleum refining, transportation of fuel, burning of fuel in diesel engine, generation of electricity, use of electricity in motor.
3. All the steps up to a petroleum fuel as outlined above, then, assuming the battery was charged by the car and not an AC battery charger, burning fuel in auto engine, generation of electricity, charging of battery, electric motor.
4. Processing of raw materials for battery (this is a step because it is the supply of energy to the processing which puts the latent chemcial energy into the materials), battery converts chemical energy to electricity, bulb converts electricity to light.
5. Fusion in the sun, photosynthesis in plants, respiration in you, bicycle.
6. The student must make an explicit assumption about where the electricity is coming from. Suppose it's nuclear. Fission in reactor, generation of steam, production of motion in turbine, motion to electricity in generator, transmission, electric motor, compressor.

II. Five percent (5%).

Homework Assignment

I. Here are some uses people make of energy. For each use, try to think of at least two or three other parts of the system the energy would have gone through before it reached the use described.
1. In an iron stove, a villager in India burns dried cow dung to cook a meal.
2. Electric motors turn the wheels of a diesel-electric locomotive.
3. The electric starter on an automobile turns the engine over, but it won't start yet.
4. A policeman's flashlight picks out a burglar breaking into a store.
5. You bicycle to school.
6. An air conditioner cools a house.

II. Here are the efficiencies of various parts of the automotive system. Calculate the system efficiency.

Production of crude oil	96%
Refining of crude oil	87%
Transportation of gasoline	97%
Thermal efficiency of auto engine (only part of the heat is changed to motion)	29%
Mechanical efficiency of engine (some of the motion goes to the fan, etc.)	
Rolling efficiency (energy lost flexing the tires, for example)	30%

III. Read the pages in the booklet with the headline, "Energy, Rules of the Game."

Unit Two
Energy from the Sun

Wind Cycles

Objectives

This lesson contributes to developing the students' understanding of the following concepts:

The energy of winds and storms comes from the sun.

Unequal heating of different parts of the earth is the fundamental cause of winds.

Format of the Lesson

Convection currents demonstration

Wind cycle box demonstration

Land and sea breezes

Materials Needed

candle

spinner made of a throw-away aluminum tart pan. (Note that we aren't throwing it away.) With a needle, punch three equally-spaced holes in the rim. Suspend the pan upside down from a single thread by running a thread through each of the three holes, and knotting them together with a fourth thread. With scissors, cut radial slots up to about 2 cm from center of the pan. Twist the resulting vanes, all in the same direction.

swivel preferably ball-bearing, such as Sampo number 3SB, three for $2.50 at sporting goods stores. Less expensive barrel swivels can also be used.

balloon (optional) If you choose to do this activity, you need two fairly large balloons, preferably dark-colored. Blow them up and tie them with string, hang them about 10 cm below the ends of a bar about a meter long. A good kind of bar to use is a one-eighth-inch metal bar, available at hardware stores for about 80¢. File a notch 1 cm from each end to which to tie the balloons; file a flat in the middle. Balance the bar on a single-edged razor blade stuck edge up in a piece of cork or beadboard. If you put the cork on the corner of a table, the balloons can hang down without touching the table leg. You will also need a heat lamp to heat one of the balloons. See the drawing on the next page.

overhead transparency **Land and Sea Breezes.** Make from master at the end of this lesson; you may want to have it colored with felt pens.

cardboard box about 30 cm by 30 cm by 60 cm. Dimensions are not critical.

cardboard tubes like those that come in the middle of rolls of paper towel. Should be about 30 cm long.

saw for cardboard

aluminum foil

black construction paper or black paint. Poster paint will do, or (if for teacher use) a can of black spray paint.

masking tape

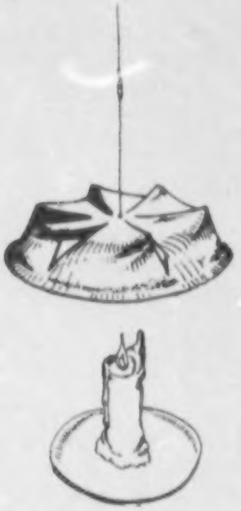
plastic wrap

fine strips of tissue

a sunny day or at worst an intense incandescent light source.

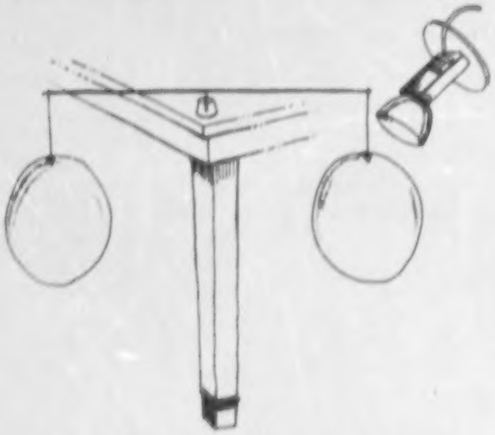
Convection Currents

Light a candle and suspend the spinner above it. (Alternatively, and more fun, you may have one of those Scandanavian Christmas decorations in which hot air rising from candles causes brass angels to revolve and strike bells.) Ask students were the energy to make the spinner turn is coming from (ANS: Chemical energy in the candle, to heat energy, to motion of the spinner.)



What causes the spinner to turn? Some student will probably respond that hot air rises and that turns the spinner. This is correct and you may wish to leave it at that. (The spinner is really a kind of turbine, converting a linear flow of fluid into rotation of a shaft.) Or, you may wish to extend the discussion into convection currents and buoyancy.

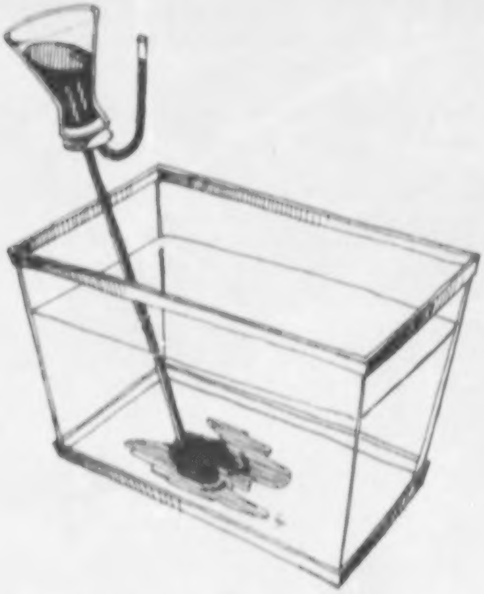
A good demonstration of the buoyancy of warm air is the balloon balance. Adjust the balance until the two balloons just exactly balance. Then heat one of the balloons with a lamp (from the side, because putting the lamp directly beneath the balloon creates an air current that could push the balloon up). The balloon will increase in size, and at the same time the scale will become unbalanced, with the heated balloon rising.



We have the same number of molecules in the balloon as before, but now they take up more space. So the air in the balloon is less dense than it was, since density is a comparison between mass and volume. Less dense fluids float to the top of denser fluids, in this case the colder the air in the room.

For your own information, note that in our experiment air pressure was kept relatively constant, because the balloon resists expansion fairly weakly. When the difference between the pressure inside and outside the balloon get too great, the balloon compensates by expanding. In the atmosphere, however, differences in heating by solar radiation are transformed into differences in air pressure.

To show convection currents created by temperature differences, and to demonstrate that "hot air rises" doesn't just apply to air, set up an aquarium full of cold water. Use a glass tube to inject a slug of hot water colored with dye into the bottom of the aquarium, as shown in the drawing. What happens to the hot water?



Conclude that a difference in temperature could create movement in nature just as it does in a heat engine.

Demonstration of the Wind Cycle Box

You may choose to have this apparatus assembled in advance by students, or you may want students to build it as a class activity. Construction directions are given on the activity sheet. Following the investigation, discuss the questions at the end of the activity sheet. Conclude that light energy can lead to heat which then can cause a movement of air.

Sea Breezes

Review the results of the activity in which we discovered that jars of air, water, and soil, warmed by the sun, did not change temperature at the same rates.

Put on the overhead transparency of land and sea breezes. Ask the students which will warm up faster after sunrise, the land or the sea? Which will be warmer by noon? Mark the transparency to show the hot air rising over the land and the cooler air coming in from the sea.

What will the situation be at night, after the sun goes down? The ocean will hold its heat better than the land. Now warm air will be rising over the ocean and air cooled by contact with the land will flow toward the sea. The land breeze is much weaker than the sea breeze, however.

With many additional complications, this is basically what causes all winds.

Projects for Independent Investigation

1. If the poles (North and South) are the coldest parts of the earth and the equator the warmest, why do the winds in our country mostly blow from west to east, instead of from north to south? Investigate the Coriolis Effect and write a report on it.
2. What causes currents in the ocean like the Gulf Stream?
3. Is the way you fly a hot-air balloon affected by how sunny the weather is and, if so, how?

A Box of Wind

In this investigation, we will try to see whether light energy can cause air to flow. To make the apparatus, you will need:

☐ a cardboard box

☐ aluminum foil

☐ black construction paper or black poster paint

☐ two cardboard tubes

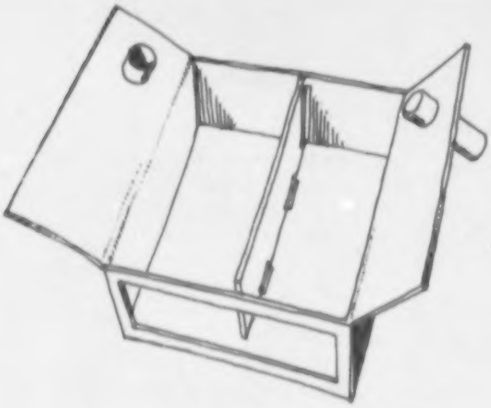
☐ tape

☐ plastic wrap

☐ fine strips of tissue

Do you have everything you need?

Procedure



Step One: Cut a window that takes up most of one long side of the box (not the top or bottom).

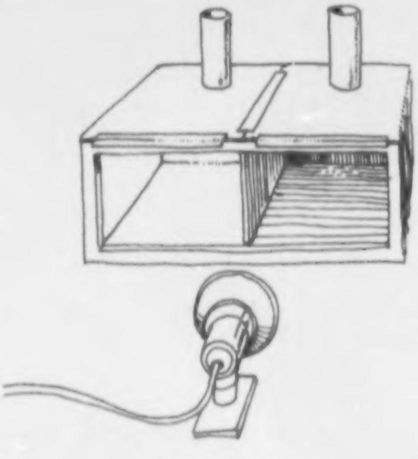
Step Two: Cut a piece of cardboard to fit inside the box. It should be just as high as the box is high, and about 5 cm shorter than the width of the box. You can probably use one of the box flaps for this. Tape this piece of cardboard into the box, dividing the box in half. Leave the 5-cm gap on the side in which you cut the window.

Step Three: Line half the box with aluminum foil. Line the other half with black construction paper, or paint it black.

Step Four: Cut two holes big enough to fit the cardboard tubes. The holes should be on top of the box, one on each side, and very near the side of the box opposite the window. Put the tubes in the holes, leaving as little tube sticking in the box as possible. Tape the tubes in place, sealing the hole with tape.

Step Five: Cover the window with plastic wrap, taping it in place.

Step Six: Let the sun or a very strong light shine on the window side of the box. After a few minutes, hold pieces of fine tissue near the tops of the tubes.



Questions to Answer on a Separate Piece of Paper

1. Is air moving in the tubes? Which way?
2. Which side of the box do you think is hotter? Why?

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The Water Cycle

Note: The two demonstrations in this lesson can only be done on a bright sunny day.

Objectives

This lesson contributes to students' understanding of the following concepts:

Heat produced by the absorption of sunlight promotes the evaporation of water.

A temperature difference can be used to produce motion.

Water goes round and round in the water cycle and is not used up.

The water cycle is driven by energy from the sun.

Through hydroelectric plants, we get electrical energy from the water cycle.

Format of the Lesson

(Prepare waterwheel in advance)

Discuss and demonstrate evaporation

Distribute observation sheets

Take class outside

Demonstrate water-cycle jar

Allow students time to complete observation sheet

Briefly discuss hydroelectric power

Materials Needed

dishes two, preferably dark colored

glass jar one gallon. $1 at supermarkets. Though the trend is to plastic, these can sometimes be salvaged from cafeterias or restaurants. The jar **must** be clear.

aluminum foil heavy-duty, about one square foot.

wire coat hanger or similiar gauge.

tape such as Scotch® transparent tape.

ruler

ice cubes about one tray-full.

water

black construction paper one sheet. Cut a circle from this paper just big enough to fit in the bottom of the gallon jar.

corrugated cardboard beadboard, or any other insulator big enough to rest the jar on it.

worksheets **Observing a Water Cycle Jar,** one per student

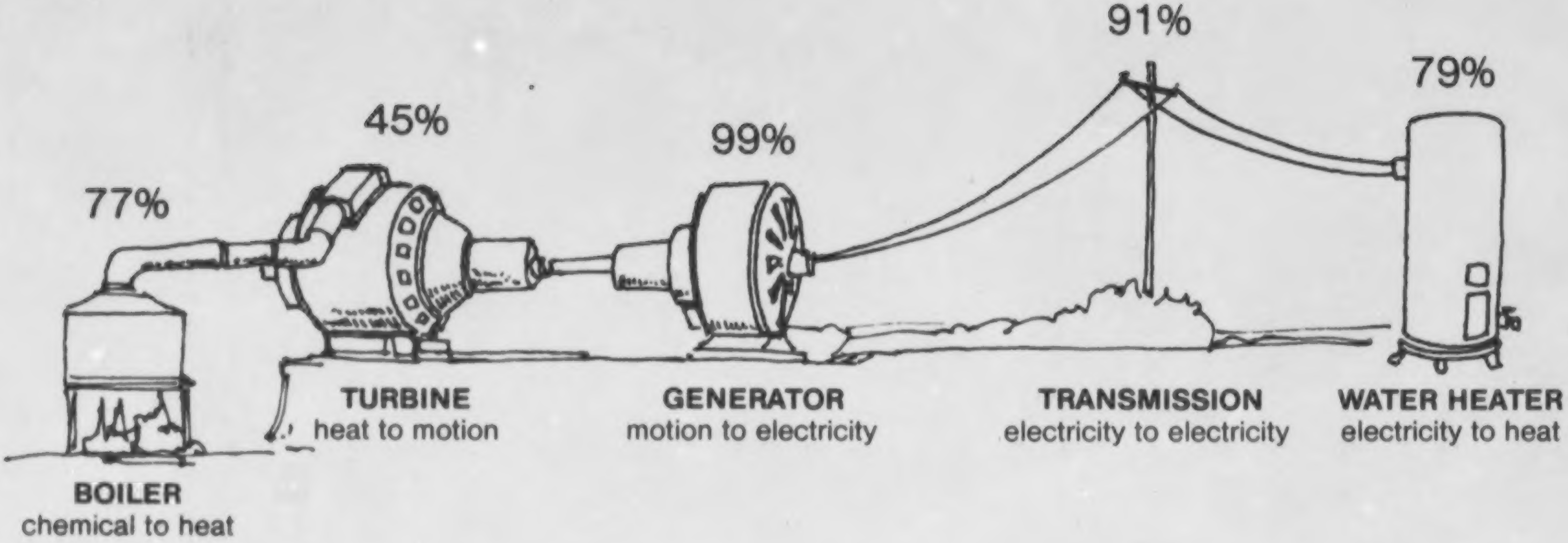
overhead transparency **The Water Cycle**

Building the Waterwheel

We suggest that you or a student build and test the waterwheel prior to class. To enable a student to do it, directions are provided on a separate activity sheet.

Evaporation

Put out two shallow dishes of water, one in a sunny location and one in the shade. Mark the water level on each. Be sure the two locations have comparable windiness.


77%
45%
99%
91%
79%
BOILER
chemical to heat
TURBINE
heat to motion
GENERATOR
motion to electricity
TRANSMISSION
electricity to electricity
WATER HEATER
electricity to heat

Ask students to predict what will happen.

Ask which will get warmer, the water in the sun or the water in the shade?

After the water has evaporated, ask what happened to it? Define the word evaporated: water molecules escaped from the surface of the water into the air above. There they are invisible water vapor. The chances of a molecule's escaping depend on its speed; the faster it goes the better the chance of escaping. An increase in temperature means an increase in the average speed of the random motion of the molecules. The higher the temperature of liquid water, the more molecules will be moving fast enough to escape. In this way, sunlight promotes evaporation by heating water on the earth's surface.

Can the molecules of water vapor ever become liquid water again? Yes. They will condense when the air gets colder. Clouds are made of tiny droplets of condensed water.

Demonstrating the Water-Cycle Jar

Tell the class we are going to see how evaporation and condensation, working together, can create an energy flow.

Pass out the observation sheets.

Take the class outside, into direct sunlight.

Place the gallon jar in full sunshine on top of a sheet of insulating material, such as corrugated cardboard, beadboard, or even a folded newspaper.

Put the circle of black paper inside the jar, on the bottom.

Pour in water to a depth of 3 cm.

Insert the waterwheel. Position it so that one side of the wheel is exactly in the center of the bottle.

Cap the bottle with the aluminum foil cone (or a metal funnel plugged with a stopper). Fold the foil edges over the bottle neck, not too tightly, because you may wish to adjust the cone later to get the drip line directly over the waterwheel.

Fill the cone with ice cubes.

Cover the top of the cone loosely with a small piece of foil with a sheet of paper under it, just big enough to shield it from the sun.

Give each student a chance to observe what happens. It may be several minutes before there will be enough meltwater in the cone to cool the entire surface of the cone evenly.

Complete answers to questions while the jar can be observed. Return to the classroom.

After the Demonstration

Discuss the questions on the worksheet. Try to develop an understanding of the constancy of the amount of material, the energy flow involved (light→heat→motion), and the processes of evaporation and condensation.

Put on the overhead transparency. (You can make this more attractive by having a student color it with permanent felt tip pens.) Compare what happened in the jar with what happens on earth.

Projects for Independent Investigation

1. Choose one of the big hydroelectric dams in the United States. Find out when it was built, who built it, and what the electricity produced is now used for. Report to the class.

2. Write a description of a violent storm you have experienced.

3. What causes the dew on grass or cars early in the morning?

Making a Waterwheel

To do this, you will need:

- *ruler*
- *scissors*
- *drinking straw*
- *heavy aluminum foil*
- *coat hanger wire*
- *tape*

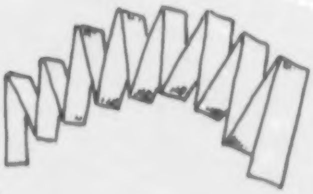
Do you have everything you need?

Procedure

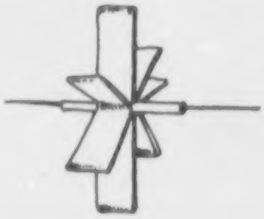
Step One: Cut a strip of heavy-duty aluminum foil 30 centimeters long and 1 centimeter wide.

Step Two: Mark this strip into 2.5-cm sections.

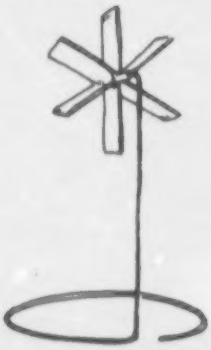
Step Three: Fold the strip into a zigzag pattern at each of the 2.5-cm marks.



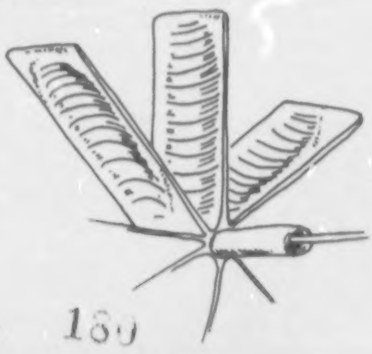
Step Four: Form the zigzag pattern into a circle. Tape the sections together as shown in the diagram, with a piece of drinking straw in the center. The straw is the bearing.



Step Five: From a coat hanger wire, make the axle and base as shown in the drawing. The upright of the base should be about 6 cm high.



Step Six: With thumb and forefinger, shape the end of each segment of the wheel so it forms a little cup to catch the falling water.



Observing the Water-Cycle Jar

On a separate sheet of paper, answer these questions:

1. Describe how the foil cone looked before we put in the ice cubes. How did it look after five minutes?

2. Where did the water dripping from the foil come from?

3. Was there more water in the jar at the beginning of the investigation or at the end?

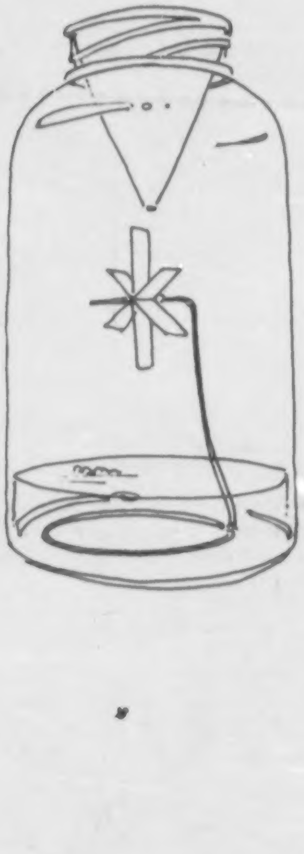
4. What do you think would happen if we had left the top of the jar open?

5. Why did it take several minutes before the waterwheel started turning?

6. Where did the mechanical energy turning the waterwheel come from? Make a diagram with arrows.

7. Suppose we had filled the cone with boiling water instead of ice cubes. What do you think would have happened?

8. (Optional) Show that the water-cycle jar is a heat engine, just like a steam engine, steam turbine, or gasoline engine.



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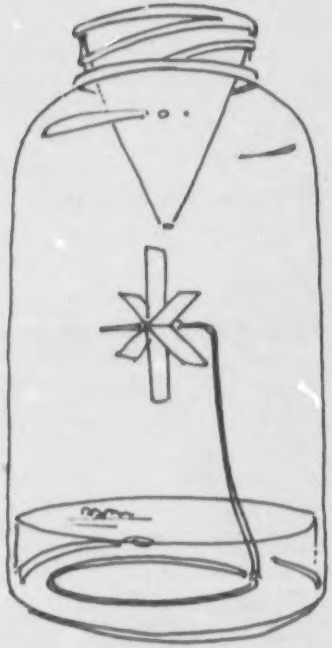

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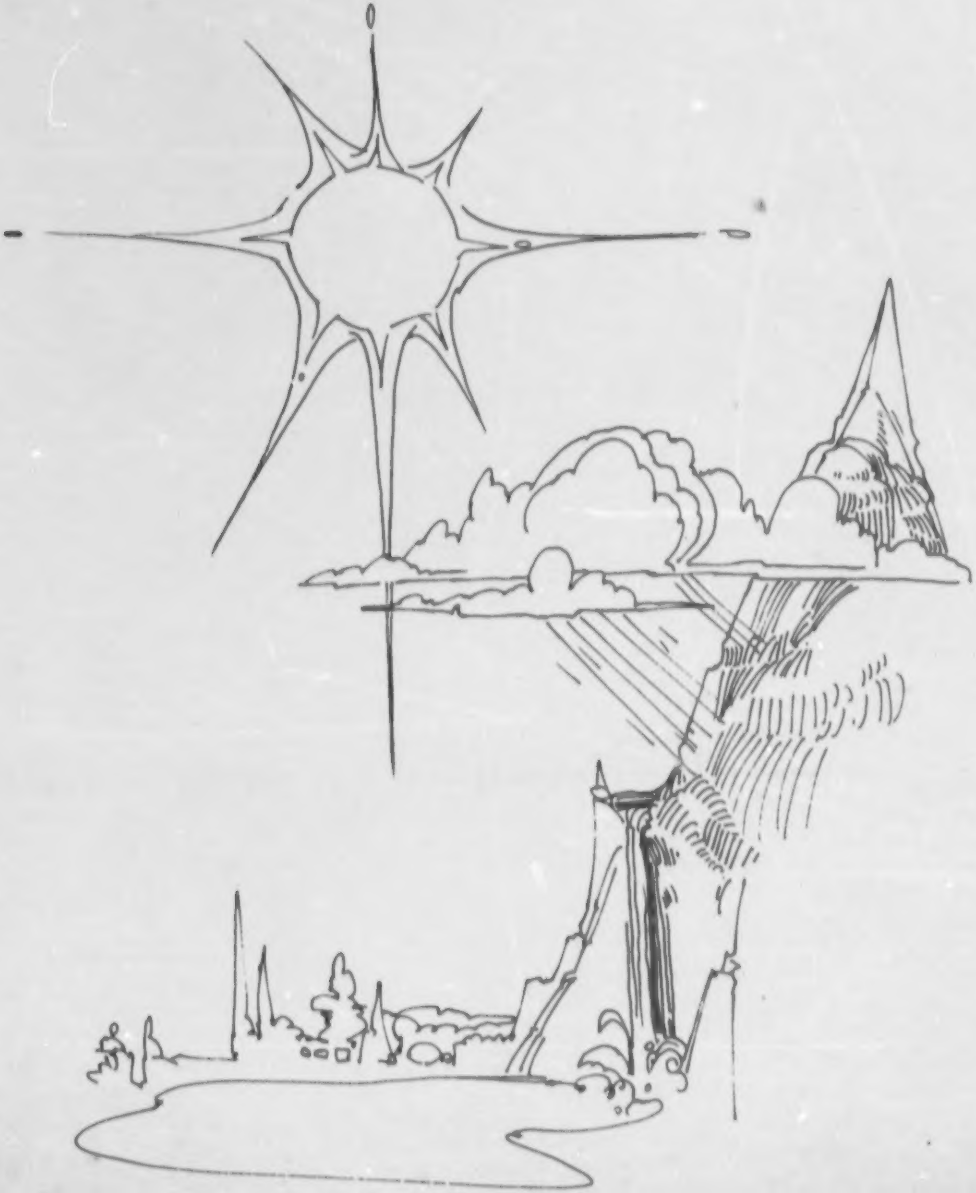

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Measuring Food Energy

Objectives

This lesson contributes to developing the students' understanding of the following ideas.

Food contains stored chemical energy.

The chemical energy stored in food can be converted to heat by oxidizing the food (combining it with oxygen).

We can measure the amount of energy stored in food.

Vocabulary

small calorie
food Calorie
calorimeter
milliliter
gram

Format of the Lesson

Review by discussion the role of sunlight in growth of plants, and of plant materials in life of animals

Discuss the calorie as a unit of measurement

Divide the class into groups

Pass out the worksheets

Release the materials and conduct the experiment

Discuss results

Assign homework

Materials Needed

wire coat hanger one for each group.

heat resistant test tube one per group.

aluminum foil about 30-cm-long piece per group.

modeling clay

straight pins one per group.

peanuts one per group, in shells.

thermometer graduated in degrees Celsius, one per group.

pliers several pairs.

matches

water

calorimeter one prepared in advance as an example.

(*scale* accurate to .01 gm, optional.)

activity sheet **A Nutty Way to Measure Calories.**

worksheet **Peanut Calorie Calculations.**

Teacher Background

Most people are familiar with the calorie tables used by people who are trying to lose weight. These tables give the energy content of various foods, as measured in Calories (capital C). Unfortunately, there is a very messy and confusing distinction between Calories and calories. A calorie, as we learned in Unit One is the amount of heat needed to raise the temperature of one gram of water one degree Celsius (to be strictly accurate, at 15°C). A food Calorie (capital C and also sometimes called a kilocalorie) is one thousand small calories, or the amount of heat needed to raise one kilogram of water one degree Celsius.

To measure the number of calories in a sample of food, it is burnt and the heat produced is measured. Usually, this is done in a special apparatus called a calorimeter. Obviously, the calorimeters we make in this experiment will not give accurate results. They do adequately illustrate the concept, and the activity reinforces the students' recognition that the energy of sunlight has been stored in the food.

For Discussion Before The Experiment

Establish through discussion a consensus among the students that there must be energy stored in food. Review that it gets there through photosynthesis.

Set a problem: Do all foods have the same amount of energy? Does a pound of hamburger provide the same amount of energy as a pound of cheese?

How can we measure the amount of energy stored in a piece of food?

Students may have a variety of suggestions: e.g., feed it to animals and make them work, etc.

Discuss the suggestions and point out that, whatever method we decide to use to measure the energy, the first thing we need is a unit of measurement.

Establishing a Unit of Measurement

Write "calorie" on the board.

(For students who have done the activities in Unit One, this will be a review.)

Define calorie: the amount of energy needed to raise the temperature of one gram of water one degree Celsius.

One gram of water has a volume of almost exactly one milliliter.

Define food Calories as one thousand small calories.

So, to measure the calories in food, we have to use those calories to warm some water.

Respiration Outside the Body?

The purpose of this short discussion is to convince students that burning a food provides the same amount of energy as the process of respiration would.

Write the equation for respiration on the board.

$[C\,H_2O] + O_2 \rightarrow CO_2 + H_2O$ + energy

What's happening? What is combining with what? Do you know any other chemical reactions where things combine with oxygen? (ANS: Burning, rusting.)

Suppose we took some carbohydrate — write $C_6H_{12}O_6$ on the board — and burn it. What would we end up with? (ANS: Water and carbon dioxide.) Write out the chemical equation. It's the same as respiration! Since we start with the same things, and end up with the same things, the amount of energy we get out must be the same, too.

To Weigh or Not to Weigh? —for Your Information Only

A more precise way of conducting this experiment is to weigh a peanut before and after burning it. It then becomes possible to calculate a calories per gram value for peanuts and, in addition, you don't have to burn all of the peanut. If you have a balance available and the students are sufficiently proficient, this is a better way to do the experiment. Ditto off a sheet with blocks in which students can record their results.

We've assumed you don't have a balance and you want to keep the activity as simple as possible. In this case, the peanut has to be burned to ashes and, unfortunately, this can be a bit time-consuming.

Setting Up the Experiment

Be sure all students are able to read their Celsius thermometers.

Show the prepared model of the calorimeter.

Divide the class into groups and arrange seating appropriately.

Distribute worksheets and materials.

After the Experiment

Calculating calories

On the chalkboard, put the formula:

calories = (rise in temperature in degrees Celsius) times (grams of water)

Have each group of students calculate the number of calories produced by burning their peanut. Convert to food Calories (kilocalories).

Sources of error

How accurate do you think the measurement is?

What might be some sources of error?

Did all of the heat produced by the burning peanut go into the water?

Why must the water we start with be room temperature? Suppose the water were colder than room temperature, what would happen during the experiment? In which direction would our results be off? What would happen if the water were warmer than room temperature?

Do you think our measurement is too high or too low?

When scientists use a more precise apparatus to measure the calorie content of peanuts, they get a value of about 5.59 Calories per gram of peanut. (A typical peanut weighs about one gram.) On the basis of your results and the way you got them, does it seem to you that 5.59 Calories per gram might be a more accurate value?

Homework Assignment

Make a record of all the food you eat for two days. From a Calorie chart, determine how many Calories were in each item eaten. How many Calories per day are you eating?

Peanut Calorie Calculation

Amount of water used = ____________ milliliters = ____________ grams.

Temperature of water in °C before burning peanut = ____________ °C.

Temperature of water after burning peanut = ____________ °C.

Difference in temperature = ____________ degrees.

calories = (mass of water in grams) x (temperature change in °C)

An example

Ten grams of water are heated 15°C.

calories = (10 grams of water) x (15°C)

calories = 150 calories

Use the above formula and your measurements to calculate how many calories of heat were obtained from the peanut.

calories = ____________ grams x ____________ °C

calories = ____________ calories

This calculation is in small calories. There are a thousand calories in a food Calorie, or large Calorie. To convert calories to Calories, divide the number of small calories by 1000.

$$\text{large calories} = \frac{\text{small calories}}{1000}$$

Example:

$$\text{Calories} = \frac{150 \text{ calories}}{1000}$$

Calories = 0.15 Calories

How many food Calories did burning the peanut add to the water?

$$\text{Calorie} = \frac{\text{calorie}}{1000} \qquad \text{Calories} = \frac{\_\_\_\_\_\_\_\_}{1000}$$

A Nutty Way to Measure Calories

In this experiment, we want to measure how many calories of food energy are in a peanut. A calorie is the amount of heat needed to raise the temperature of one gram of water one degree Celsius. One gram of water has a volume of one milliliter.

To find out how many calories are stored in the peanut, we will burn it and use the heat produced to warm some water. Then, knowing how many grams of water were warmed and how much they were warmed, we will calculate the calories.

Check to see if you have all the materials you need.

☐ one wire coat hanger

☐ one test tube (heat resistant)

☐ aluminum foil

☐ clay

☐ straight pins

☐ peanuts

☐ pliers

☐ graduated cylinder

☐ Celsius thermometer

☐ matches

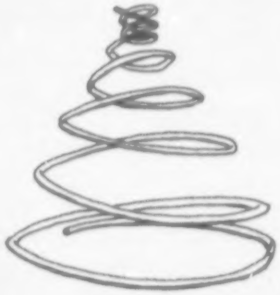
☐ water

Procedure

Step One. Cut and form the wire from the coat hanger into the shape of a spiral. The diameter of the base should be 8 or 10 cm across.

Continue the spiral upward.

Complete the structure by making two small loops to hold the test tube.



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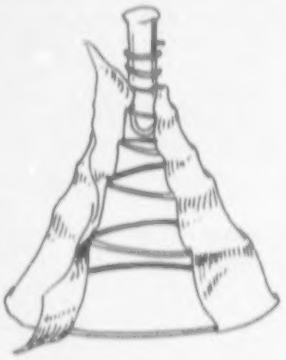
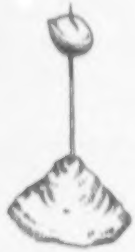
Step Two. Place the test tube through the two small loops. For safety, wrap the test tube with paper towels while doing this part. Make an aluminum foil shroud to extend from the top loop to the base. Make an opening for a door.



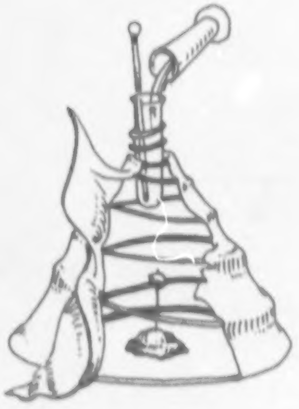
Step Three. Calorie measuring time.



Embed the head of a pin in a hunk of clay. Place a shelled peanut on the point.

Measure 10 milliliters of water and place it in the test tube. How many grams does 10 milliliters of water weigh?

Take the temperature of the water. Record your measurement.



Light the peanut with a match. As soon as it starts to burn on its own, place it under the test tube in the calorimeter, and allow it to burn.

If the peanut sputters and goes out before it looks all burnt up, get a new peanut and fresh water, and start over.

When the peanut looks all burnt up and goes out, take the temperature of the water again.

Calculate the calories.

Tracing Your Own Food Chain Backwards

Here are some things we eat. Find out what's in them and follow their food energy back to green plants. If you're not sure, guess. One example is done for you.

food	ingredients	animals along the way	green plants
birthday cake	flour		wheat
	sugar		sugar cane, sugar beets
	eggs	hen	wheat, corn
	milk	cow	grass, corn, hay
	butter	cow	grass, corn, hay
	salt		no food energy
	baking powder		no food energy

Now you do a hamburger, a breakfast cereal, and two foods you choose. Use more paper if you need.

Transportation in the Food System

To do this project, you need a list of food. This list can be:

☐ a typical day's menu chosen by the class

☐ all the food you ate in one day

☐ all the food you family bought on one trip to the market

Put a check in the box that tells what kind of list you are using.

In the table below, write the name of a food and in the next column the name of the state or country it came from. (If you are not sure where it came from, study the packaging and make an educated guess. Be ready to explain the reasons for your guess.) Some examples are done for you.

orange juice	Florida
oatmeal	Minnesota
raisins	California

Unit Three
Fossil Fuels
History & Technology

People and Fuel

Objectives

This lesson contributes to students' understanding of the following concepts:

Prehistoric people used fuel for warmth and cooking.

By the time of the Romans, fuel was used to extract raw materials and manufacture things.

Today we use fuel for earlier purposes, and also to get mechanical power.

Format of the Lesson

Discuss "cavepeople's" use of fire

Read Pliny aloud in class

Discuss use of fire 2000 years ago

Discuss fire today

Distribute homework sheet

Materials Needed

list of fuel sources used by local utility. Get this information by phoning them.

chalkboard

Preliminary Discussion

Develop students' ideas about early men, "cavemen." Ask how they got their food. Ask what use students think cavepeople made of fire. List these uses on the chalkboard. How might they have started fires? What do you need to have a fire? Stress to the class the necessity of having something to burn. (Define fuel as something to be burnt.)

If you have completed the previous unit, including the origin of fossil fuel, the discussion of fuel can be brief.

By the Time of Ancient Rome

Go over the chalkboard list of the uses the students have suggested that cavepeople might have made of fire. Point out that even today there are primitive people who use fire for only these uses. (The Tasaday in the Philippines.) But by the time of ancient Greece and Rome people had learned many other uses for fuel.

Help the class to recall what they know of Greek and Roman times. Then read the selection from Pliny aloud.

> We cannot but marvel at the fact that fire is necessary for almost every operation. It takes the sands of the earth and melts them, now into glass, now into silver, or minium, or one or other lead, or some substance useful to the painter or the physician. By fire minerals are disintegrated and copper produced: in fire iron is born, and by fire it is subdued: by fire gold is purified: by fire stones are burned for the binding together or walls of houses . . . It is only when ignited and quenched that charcoal itself acquires its characteristic powers, and only when it seems to have perished that it becomes endowed with greater virtue.

Pliny the Elder, *Natural History*, Vol. XXXVI (Pliny died in the volcanic eruption that buried Pompeii in 79 AD).

Explicating Pliny

Many classes can figure out what Pliny is talking about without prompting. It isn't necessary that every word be clear, but that the general idea of extending the use of fuels to the production of raw materials be clear. For your information only, some comments on Pliny:

"glass" is made from sand heated with other substances

"minium" = red lead, lead oxide used as a paint pigment

"minerals are disintegrated and copper produced" = smelting of copper ore

"iron is born" = smelting

"subdued" = tempering of iron, a way of altering its hardness

"gold is purified" = refining

"stones are burned" = making lime by heating limestone. Lime is used for mortar. Portland cement is made by a similar process.

"charcoal ignited" = pyrolysis of wood

Make a list of the uses Pliny mentions. What uses for fire does Pliny mention that cavepeople would not have known of?

Make the point that we use fire for all the uses the caveman did, and all the uses the Greeks did, and we have added some of our own. And there has been another very significant change: we use fossil fuels.

Pass our the worksheet **Fuels in Your Life.**

Go over the worksheet to be certain students understand how to complete it, and supply the data needed on fuels burned by the local power company.

Projects for Independent Investigation

1. Read the Greek myth of Prometheus. Tell the story to the class. What did Prometheus do? Why did the gods think his action was so important? What does this myth tell us about the importance of fire to the ancient Greeks?
2. Make a timeline as a wall poster, starting at 2000 B.C. and going to 2000 A.D. Mark important changes in people's use of energy on the timeline as you learn about them.
3. If you don't already have fire, how can you make it? Demonstrate for the class how people could start fires from friction (boy scout rubbing two sticks together) or flint and steel.

Fuels In Your Life

Fill in the blanks below by writing the name of the fuel you use to do the job.

You may use electricity to do some of the jobs. Your teacher will tell you what the power company in your community uses to generate the electricity it sells. Write the percentages down:

Non-fuel sources:

hydropower: ________%

geothermal: ________%

windpower: ________%

nuclear: ________%

From burning fuels:

natural gas: ________%

petroleum: ________%

coal: ________%

wood + wastes: ______%

If you use only electricity for one of the jobs below and none of your city's electricity comes from burning fuels, write "nothing" in the blank, Otherwise, write the names of the fuels the company uses.

1. To keep my home warm, we burn ____________________.
2. To make our car move, we burn ____________________.
3. To plow the fields and plant the food I eat, the farmer burned ____________________.
4. To warm water at our house, we burn ____________________.
5. To cook our food, we burn ____________________.
6. To clean our clothes, we burn ____________________.
7. To light our house, we burn ____________________.
8. To make the iron in our automobile, the steel company burned ____________________.

A. Which of the uses above would a caveperson have understood? Numbers: ____________________.

B. Which of the uses above would Pliny have understood? Numbers: ____________________.

C. Which uses are unlike any Pliny would have known of? Numbers: ____________________.

D. Of the fuels listed, which do you guess might have been familiar to the caveperson? ____________.

E. Of the fuels listed, which do you guess might have been familiar to Pliny? ____________________.

Wood or Coal?

Note: You will need to do part of this lesson out-of-doors, because of the smoke produced.

Objectives

This lesson contributes to students' understanding of the following concepts:

There are different kinds of coal.

Coal produces undesirable by-products when it burns.

People knew of coal for hundreds of years before extensive use was made of it.

Format of the Lesson

Handling of coal samples

Burning of wood and coal

Discussion of English coal laws

Materials Needed

coal sample Purchase from a local coal dealer or from a mineral supply house such as Wards. One hundred pounds of blacksmith coal costs about $8.00; share with other schools.

hot plate hibachi, or similar grill. This will be used to ignite the samples. If an electric hot plate is used, provide a heavy extension cord to reach outdoors. If you use a charcoal grill, light it far enough in advance that it produces no flame or smoke to confuse observations.

scale a simple balance will do. Devising such a balance can be an exercise for a group of students.

wood a piece of scrap lumber the same weight as a piece of coal you have.

reading **A Royal Proclamation,** one for each student

Preliminary Discussion

If you are using a charcoal grill, preheat it prior to the discussion. Pass around the coal samples. Select a piece of bituminous coal about as large as a walnut. Select a piece of wood of approximatly equal weight. Ask students when they think people first used coal as fuel.

Some examples:

Chinese at least 100 B.C., some believe 1000 B.C.

Medieval Europe 1200 A.D. (blacksmiths)

Hopi Indians 1200 A.D.

So by the early Middle Ages Europeans knew about coal.

But most people burned wood or charcoal – as many people still do.

Why did people burn wood instead of coal? Let's make some observations.

Pass out the observation worksheet (or put the questions on the chalkboard for copying) and take the class outside.

Experiment

Counsel the students to observe the burning closely. Place the wood on the hotplate or the iron grill of the hibachi. Observe the burning. Repeat with coal. Remove the ash for examination. Secure the safety of the site and return to the classroom.

Discussion

Compare observations. Students will have noted the more objectionable air pollution from coal.

Confirm that most people did not regard coal as the ideal fuel, compared with wood.

A Royal Proclamation of 1307

On June 12, 1307, King Edward I of England sent the following message to the Sheriff of Surrey, to be proclaimed. A proclamation like this was read aloud in the marketplace and other public meeting places. "Sea-coal" is what coal was called in those days. "Prelates" are clergymen; in those days much of England was owned by religious orders. "Magnates" are public officials. Look up "forfeiture" in the dictionary. Read the proclamation, and then answer the questions on a separate sheet of paper.

Of Surrey. Order to cause proclamation to be made in the town of Southwark that all who wish to use kilns in that town or its confines, shall make their kilns of brushwood or charcoal in the usual way, and shall not use in any way sea-coal hereafter, under pain of heavy forfeiture, and the sheriff shall cause this order to be observed inviolably hereafter, as the King learns from the complaint of prelates and magnates of his realm, who frequently come to London for the benefit of the commonwealth by his order, and from the complaint of his citizens and all his people dwelling there and in Southwark that the workmen in the city and town aforesaid and in their confines now burn them and construct them of sea-coal instead of brushwood or charcoal, from the use of which sea-coal an intolerable smell diffuses itself throughout the neighboring places and the air is greatly infected, to the annoyance of the magnates, citizens and others there dwelling and to the injury of their bodily health.

The like to the mayor and sheriffs of London.

1. The King says two different groups of people have been complaining to him: visitors to Southwark (the "prelates and magnates") and citizens. Which group do you think was most likely to have the King's ear?

2. Why were people objecting to the burning of coal?

3. Do you have any laws in your community that are like the King's proclamation? What actions do they forbid? Who makes the laws?

4. What was "the usual way"?

5. Do you think everyone in Southwark was happy about this proclamation? Why not?

6. Should the government pass laws to prevent "annoyance" and to prevent "the injury of bodily health?"

For Further Research

The city of Southwark became part of London a few decades after this proclamation. Find out what connections Southwark had with the writers Chaucer and Shakespeare. What connections does Southwark have with American history?

Comparing Burning Wood and Coal

Observe the burning of equal weights of coal and wood. Then answer the following questions:

1. Describe the appearance of the smoke each produced.

2. Describe the smell.

3. Do you think heat boiled gases out of the wood? Record observations to support your view.

4. Do you think heat boiled gases out of the coal? Record observations.

5. Which burned longest?

6. Which seemed to give off more heat in burning?

Wells

Objectives

This lesson contributes to students' understanding of the following concepts:

Some rocks are porous and can hold liquids in those pores.

Water can pass through some kinds of rocks but not through others.

Holes can be drilled through solid rock.

In the early days of the United States, salt water was a valuable substance obtained from wells, though it was often contaminated with oil.

Format of the Lesson

Discussion: wells for water

Demonstration: water in rock

Demonstration: percussion drilling

Teacher narrative of start of oil industry

Demonstration: kerosene lantern

Homework assignment

Materials Needed

coarse sandstone specimen hand size.

specimen of any impermeable rock such as granite, gneiss, or most shales.

water

*star drill**

*sledge hammer**

*goggles**

*a rock or brick**

overhead transparency **Percussion Drill.**

kerosene lantern

*How you teach this lesson depends on your access to some common tools used to drill holes in concrete or brick walls and floors. If you aren't familiar with these tools and don't have them at home, you can probably borrow them from the school custodian or the industrial arts teacher. Better yet, let her or one of her students come to demonstrate their use.

Preliminary Discussion

One of the things everyone needs, even more than artifical light, is water. How do people get water? Pursue the question until someone suggests wells, or digging holes in the ground.

What do you run into as you dig? (ANS: First soil and then, eventually, solid rock.)

When you reach solid rock (it's called bedrock) is there any point in going farther? (ANS: Yes, people do bore water wells beyond the soil.)

Demonstrate Porosity of Some Rock

Confirm that we do drill water wells into rocks because we often find layers of rocks holding water.

Take out the sandstone specimen and sprinkle water on it. The water will be absorbed (more quickly on some sandstones than others; check yours in advance). Let the students try this for themselves. Observe that the same thing happens when we wet concrete or plaster. Where did the water go? (We will answer this question in the next lesson.)

Now try sprinkling water on an impermeable rock. It sits on the surface, just as it would had it been sprinkled on a piece of metal. So rocks differ in whether they can hold water or not.

Because some rock layers can hold water (they are called aquifers), there is a value in being able to drill a well into solid rock. The Chinese invented ways of doing this 2,600 years ago. Let's see one way a hole can be drilled into rock.

Demonstrate Percussion Drilling

Explain to the students that we're going to make a small hole in a rock the same way people drill some wells.

The star drill is used by placing the cutting edge on the rock and striking the drill with a sledge hammer weighing at least two pounds. Nail hammers won't work. After each blow, the drill is rotated slightly to expose fresh rock to the cutting edges.

Flying rock (and sometimes metal) chips are produced, so the user **must wear eye protection.** You may want to use a clean plastic safety shield. Don't permit students to stand too close to the rock as it is being drilled.

Pass the rock around and let students examine the hole. Explain that this is how early well drilling was done. Project the overhead of the drawing and discuss how the drill worked.

This method of drilling shallow wells is still in use. Powered equipment is used to raise and lower the bit. But the Chinese (who invented this method of drilling about 600 BC) were still doing it entirely by hand as late as the Second World War. To drill a gas well to 4,000 feet took them four years and four months.

What do you think the ancient Chinese, and the Americans in the early 1800s, were most often looking for when they drilled wells?

Salt

They were looking for salt water, because without refrigeration they needed salt to preserve meat.

Drilling wells for salt water gave people experience in drilling wells.

However, they were often frustrated because the salt water they got was contaminated with petroleum.

Rock Oil

Explain that people have been using petroleum since the days of ancient Mesopotamia. In many places it seeps to the surface naturally. It was used to caulk boats, for example. But these were minor uses and there was not a great demand for petroleum.

A druggist in Pittsburgh owned some brine wells that produced a lot of useless petroleum. He got the idea of distilling the petroleum to convert it into lamp oil, for which there was great demand. But the resulting lamp oil gave off a bad smell and heavy black smoke.

Other people were making lamp oil by distilling coal and shale, somewhat as we did in a previous lesson. One brand of this oil from coal was called "kerosene," By 1840, there were about 50 coal oil plants making about 23,000 gallons of lamp oil a year, mostly from coal.

Some of these coal oil manufacturers ran "rock oil" through their distilleries. It produced a superior lamp oil.

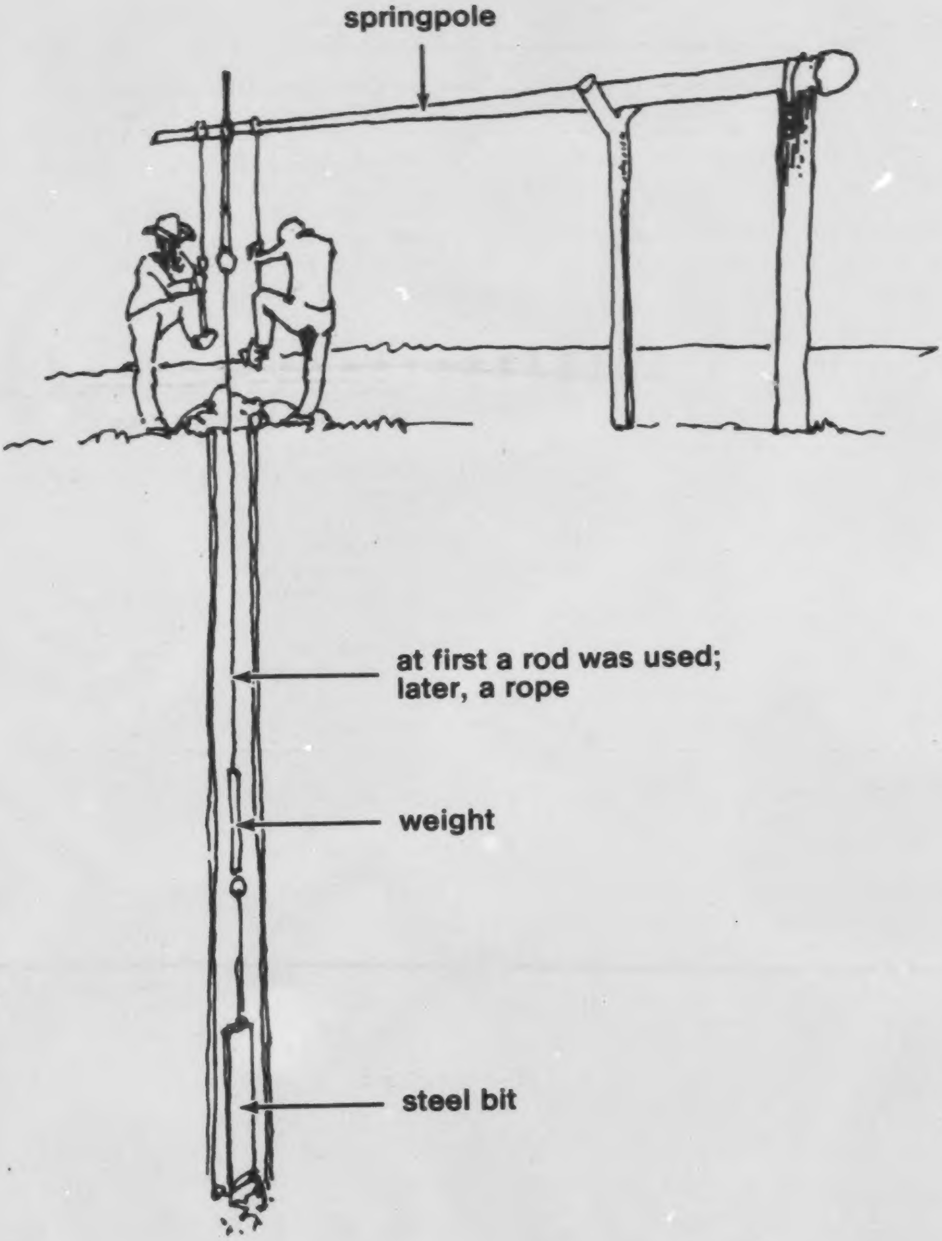
One company decided to try to use salt water well-drilling techniques to get oil. They sent a man named Edwin Drake to a place in Pennsylvania where oil was often found seeping to the surface, and he hired some men who were experienced in drilling salt water wells. On August 27, 1859, at a depth of 69½ feet, the first oil well came in!

There was soon a boom, with wells and distilleries all over the area. The product eventually got the name kerosene, from the brand name that had been used for one brand of coal oil. And why did people want this kerosene? (ANS: They wanted it for their lamps.)

(Light the kerosene lantern.) Right, that's what they wanted. This is how the whole oil industry got started, to make kerosene. In a few years people were burning American kerosene in lamps from China to Peru. Of course, the distilleries also produced a lot of useless by-products that the distillers just threw away, like gasoline!

Additional Activities

1. If there are any in your area, visit a working oil well.
2. Show the film, **Oil Well** (available on free loan from Shell Oil Company; 21 minutes, color). Exploratory drilling, both on- and off-shore. Helpful animation. Unfortunately, the vocabulary level is a bit too high to be entirely comfortable for middle school use. Nevertheless, recommended.


springpole
at first a rod was used;
later, a rope
weight
steel bit

Coal or Gas?

Objectives

This lesson contributes to students' understanding of the following concepts:

In comparison with earlier fuels, such as coal and wood, little equipment or effort by the consumer is needed to burn gas.

Household use of gas had begun by the end of the 19th Century.

Format of the Lesson

This lesson takes two days, separated by a homework assignment.

Discuss need for stoves in households

Describe activity

Assign readings

Mime starting of stoves

Compare household use of coal and gas

Materials Needed

reading **Starting a Coal Stove,** enough copies to provide one copy each for about three-quarters of the class.

reading **Starting a Gas Stove,** one copy for each of the rest of the class.

overhead **The Coal Stove.**

FIRST DAY

Preliminary Discussion

Direct the attention of the class to the role stoves play in everyone's life. One of the jobs that is done in almost every household is cooking food. To do this, people use fuel. The early settlers of North America cooked their food in their wood-burning fireplaces. By 1900, most American families used some sort of stove. Of course, they were not like the stoves we have in our homes today.

Setting Up the Activity

Ask the students to pretend they are living in the early 1900s. Tell them they are going to act out how they think people at that time would have used their stoves.

Ask the students if they know what mime is. Many may have seen a mime on television. A mime is a kind of silent actor. Mimes often pretend to be using things that aren't really there. Ask for a volunteer to mime cooking an egg on the family stove. While the volunteer does this, ask individual students to describe what the mime is doing.

Tell the class that we will act out what we would have to do using two different stoves, both of which were in use at the beginning of the century. You will give them some reading material that describes how to work the stoves. Then, tomorrow, you will call on different people to do various parts of the job.

Pass out the two readings, distributing them randomly around the class. Consider preparing a cassette for the listening center, if appropriate for your students.

SECOND DAY

The Coal Stove

Put on the transparency of the coal stove. Ask for a volunteer to act out preparing kindling for the stove, and another volunteer to describe what the person is doing.

Then follow through by assigning the jobs listed below, one by one. Assign an interpreter for each job, too. Allow students to refer to their readings while watching the acting-out. After the mime finishes, ask students if the job was properly done.

bring coal up from the basement

clean out the old ashes

lay the fire

polish the stove

add the coal

the fire goes out; what do you do now?

remove the coal

clean the stove

lay the fire

add the coal

the blue flame is gone; what do you do now?

it's burning freely; now what?

The Gas Stove

Repeat the activity with the gas stove. Only one mime and interpreter will be needed because of the ease of starting the stove.

Post-Activity Discussion

Which was easier to use, the coal stove or the gas stove?

Knowing the burden on the person using and caring for the stove doesn't tell the whole story. To make a good comparison, we need to consider the whole system. The system would include the difficulty and expense of manufacturing the stove and the other equipment needed to bring fuel to the stove, the labor of other workers, like the coal-delivery man, and so forth, all so the stove could be used to cook somebody's breakfast. Tell the class you want them to make a more detailed comparison, and in their comparisons they should try to discuss the other parts of the system, too.

Compare how hard it was to get fuel to the two stoves.

Compare how hard it was to dispose of the ashes from the two stoves.

Compare how hard it was to start the fires or regulate the amounts of heat produced.

Compare the air pollution the fires in the two stoves produced and what was done to get it out of the house.

Are there any other difficulties we haven't discussed?

Which is the simpler and cheaper stove? Why?

How does each stove depend on the help of other people? What jobs and equipment would be involved in supplying the coal? The gas?

What do you think happened to coal stove sales as more and more homes were connected to gas mains?

Have you ever heard the expression, "Now you're cooking with gas!"? What does it mean? Where do you think it came from?

Summarize that by 1900 it was evident to many people that gas was a clean-burning, easy-to-use fuel. The transition from coal to gas as a household fuel had begun.

Starting a Coal Stove

In the 1890s, many American homes used coal stoves like the one pictured below Here are instructions for starting a coal stove, from the **Boston Cooking School Text Book,** by Mrs. D.A. Lincoln, published in 1887.

Remove the covers on the top of the stove and brush the ashes from inside the stove into the firebox. Replace the covers, close the dampers and turn over the grate. Shake the lower grate, letting the ashes sift into the ash-pan; when the dust ceases to rise, brush out the oven, remove the cinders from the lower grate and reserve them to burn again. When taken out in this way, the ashes in the pan will not require sifting.

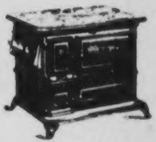
If there be no lower grate, remove the ashes and cinders together and sift them; pick over the cinders carefully, and throw out stones and clinkers. These should never be burned as they injure the lining of the fire box; but any pieces of half-burned coal, should be saved. Always take out the ashes before lighting the fire, for if they are left in the pan, sparks and lighted coals will drop into them; it is then highly imprudent to remove them, unless they are placed in a fireproof ash receiver. Fires have been occasioned by careless storing of hot ashes.

Put into the firebox, first, shavings or loosely wadded newspapers, letting them come close to the front; next, arrange fine pine kindlings crosswise and so that the air may circulate freely between the pieces; be careful to have the kindling touch the ends and sides of the firebox so that coal may not drop through to the grate. Then put on enough hard-wood, arranged in the same manner as the kindling, to come near the top of the firebox, put on the covers, open the dampers, and brush the dust off the stove.

Moisten some stove polish with cold water, and put it on the stove with the dauber; rub the blacking in thoroughly. Next light the shavings and paper in the firebox from below the grate, and while the fire is kindling, polish the stove with the dry polishing brush. Remember, blacken the stove while it is cold, but work up the polish as it begins to heat.

When the wood is well kindled, put in a few more pieces of hard-wood, and press the coals down to the grate. Next put on coal enough to cover the wood and when this has kindled, fill the firebox to the top of the lining. By making sure that the hard-wood kindles first, and adding the coal gradually, much trouble is saved; for, unless the kindling be well seasoned, and part of it hard-wood, and plenty of it used, it will either not kindle or it will burn out before the coal is ignited. In that case, the coal must be removed and the fire rebuilt from the start. The blazing heat from the wood alone warms the stoves and the oven quickly becomes hot.

When the blue flame is no longer seen (on the coals) close the oven damper; and as soon as the coal is burning freely, shut the front damper; then regulate the fire by the slide or the damper in the pipe. While starting and watching the fire, empty the teakettle, wipe the inside, fill it and the reservoir with fresh water —never from the hot water tank — finish polishing the sides and back of the range and brush up the floor and hearth.



Using a Gas Stove

GAS COOKING WITH ECONOMY.

JOHN R. SHIRLEY,
Inventor and Manufacturer of
SHIRLEY'S NEW GAS STOVES and OVENS,
Cor. Pine and Eddy Sts., Providence, R. I.

——:o:——

In introducing to the public Shirley's New Gas Cooking Stoves and Ovens, we desire to call attention to the comfort and convenience of cooking by gas, especially during the summer months when a fire is not required for other purposes. The advantages derived by the use of gas as a fuel for cooking can only be fully appreciated by those who have had experience in its extremely useful application for that purpose, but to obtain all the advantages, one must be careful to select a stove so constructed as to develop and utilize the greatest heat obtainable from a given quantity of gas.

In the construction of these stoves, great care has been taken that the gas should be so applied as to ensure perfect combustion and the smallest amount of consumption practical. That it generates and completely utilizes heat in large quantities compared with the quantity of gas consumed, is abundantly proven by the fact that it will roast a joint of meat weighing seven or eight pounds for the trifling sum of three cents.

To obtain a perfect estimate of the relative money value of Gas and Coal as calorific agents, we must take a comprehensive view of all the contingencies inseparately attached to each.

The use of coal entails first the trouble of purchase, then it must be stored away, and when it is safely in the bin, the side-walk on which it was dumped presents such an unseemly appearance that it must needs be scrubbed. Then kindlings must be purchased and stored, and as they are wanted, perhaps for use on an upper floor, both coal and wood must be carried from the cellar. When each new fire is built, the ashes from the last one must be removed from the premises, involving, no matter how careful, the scattering of some over the room, to the destruction of carpets, furniture, etc.; then comes the time lost in waiting for the fire to burn. If only a little fire is needed to boil a pint of water, substantially the same operations must be gone through with, that would be necessary to make a fire to cook a dinner. After it is built it must be watched, or it may get too hot and burn the meat, or go out and leave the water unboiled.

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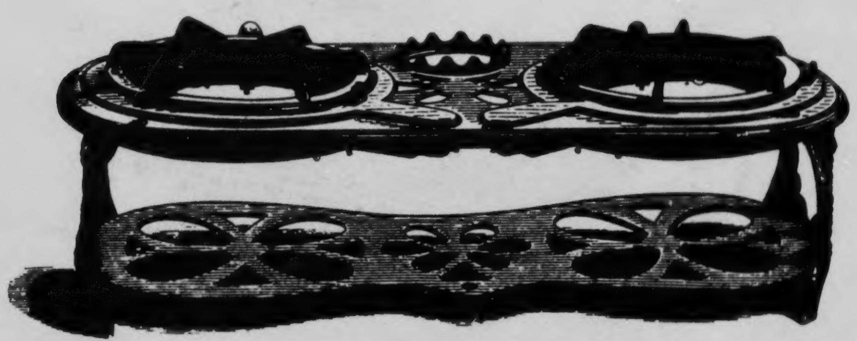
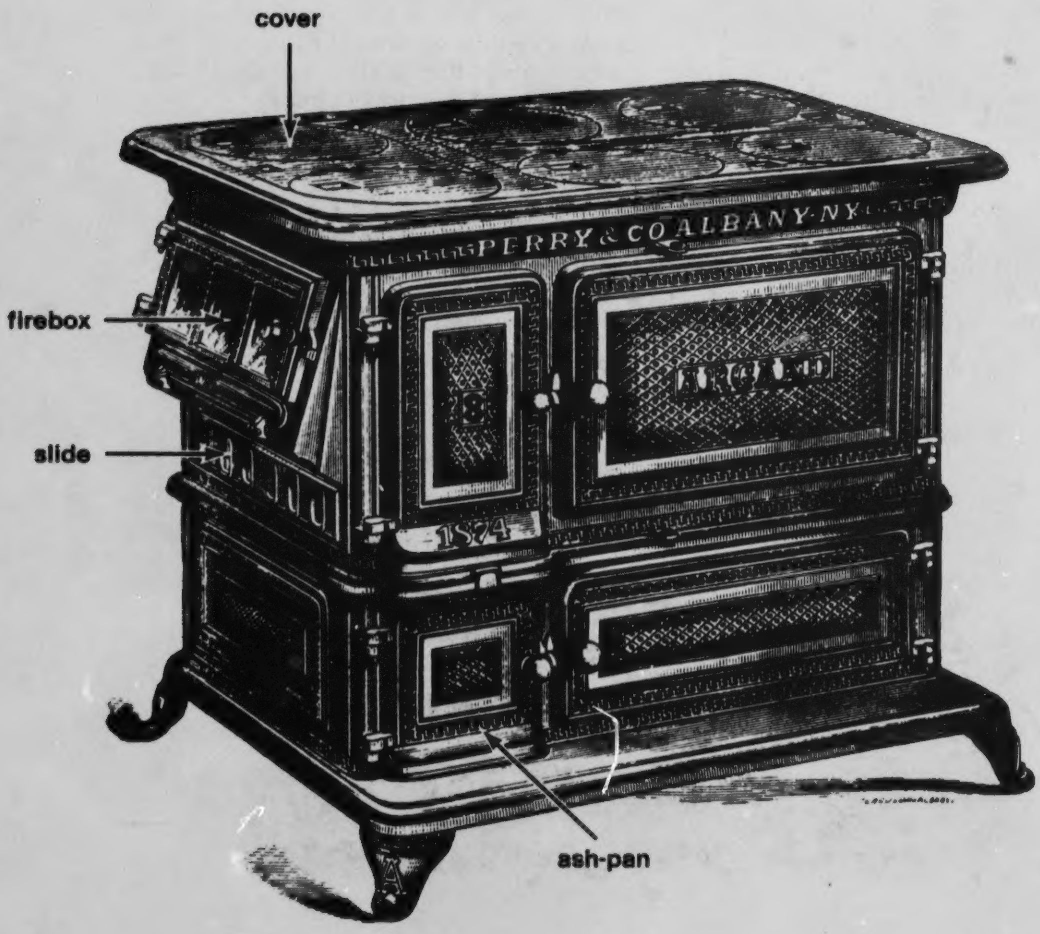
With gas all this is changed – it entails no journeys up and down stairs, it makes no dirt, necessitates no labor; it does not smoke, nor burn too fast or too slow; it requires no care. The gas has only to be lighted and adjusted to give the flames required, the food placed in the oven and, with very little experience, the time required for cooking it may be so correctly determined, that no further attention need be paid to either the fire or oven until done. The gas is instantly turned off, and thereby all the waste that occurs with a coal fire is saved.

The Oven connected with these Stoves is of much larger capacity than those usually furnished with Gas Stoves, and by the peculiar arrangement of its interior, a greater amount of heat is utilized than by methods heretofore employed. These Stoves and Ovens are for sale by the inventor, John R. Shirley, at his Show Room and Manufactory, corner of Pine and Eddy Sts., Providence, R.I., where also may be seen a good assortment of Crystal, Bronze and Gilt Gas Fixtures of his own make, and at reasonable prices.

Prices of Stoves – Single Stove, $1.75; Double Stove, $4.50; Oven, can be used on either Stove, $4.50. Liberal discount to the Trade. These Stoves sent to any address, free of package, upon receipt of price.




cover
PERRY & CO ALBANY·NY
firebox
ARGAND
slide
1874
ash-pan

Portable Power

Objectives

This lesson contributes to students' understanding of the following concepts:

Like the reciprocating steam engine, the internal combustion engine employs a piston in a cylinder.

Development of the internal combustion engine provided a lightweight, portable source of mechanical energy.

Petroleum was identified at an early date as a source of fuel appropriate for internal combustion engines.

Format of the Lesson

Review of characteristics of steam engine

Comparison of steam engine and internal combustion engine.

Rise of internal combustion engine

Materials Needed

overheads **Piston in Cylinder, Steam Engine Overlay, Internal Combustion Overlay.** Make these from masters at the end of the lesson. It is helpful if the combustion areas on the overheads are colored red to emphasize the change from external to internal combustion.

activity sheet **Portable Steam Engines**

overhead **Change in Weight of a One-Horsepower Engine.**

worksheet **Small Engines Today.**

Reviewing the Steam Engine

Using the overhead transparency, review the operation of the steam engine. Steam from a boiler enters the cylinder, the pressure moves the piston and, as the piston moves, the steam expands and is thereby cooled; the steam is exhausted to a condenser or into the atmosphere.

Remind the class what a boon the steam engine was to humankind. It provided great quantities of power on demand. Unlike the windmill, the steam engine could be operated whenever power was needed, not just when the wind was blowing. Unlike the waterwheel, the steam engine could be put anywhere, not just on rivers. But could it really be put anywhere? How portable was the steam engine?

Pass out the worksheet, **Portable Steam Engines.** Explain that this a real advertisement of an American manufacturer in the year 1860. Ask students to complete the questions at the bottom of the sheet.

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The Difficulties of Making a Portable Steam Engine

Discuss the questions. Summarize that, in small sizes, the steam engine was expensive and heavy.

One way of increasing the efficiency of a steam engine is to raise the pressure. But to increase the pressure, the boiler must be strengthened, which makes it heavier.

Efficiency can also be increased by using a condenser. But a condenser weighs something, and it needs a supply of coolant, which can be hard to get in portable applications. In steam locomotives, for example, there was no condenser. The thermal efficiency of the engine was sacrificed to decrease the weight the engine would have to pull.

Size and weight were only some of the difficulties. Handling the fuel was messy and cumbersome. It took a while to get up pressure. Some of these problems have been overcome in modern small steam engines, but back in the 1800s some of the people who were using steam engines in tractors, cars, and other machinery began to look for another, better way of getting portable power.

Internal Combustion Engine

(Replace steam overlay with the internal combustion overlay.)

The only purpose of the fuel in the steam engine is to heat water and make a hot gas: steam. There is another way to make a hot gas. Instead of burning the fuel under a boiler, we could burn it inside the cylinder itself. The burning fuel would heat the air in the cylinder, and the pressure would push down the piston. Then the air would be expelled, and a new supply of air and fuel brought in and ignited. Because the burning takes place inside the engine instead of outside, this kind of engine is called an **internal combustion** engine.

People had the idea for an engine like this as early as 1794, but they couldn't build a practical one.

What Fuel Is Suitable For Internal Combustion?

Now the question becomes, what kind of fuel is best for an engine like this?

Fuels can be solid, liquid, or gas. Which do you think would work best in an internal combustion engine? (ANS: Liquid or gas. How could we get the solid into the cylinder?)

That is what the inventors of the internal combustion engine thought, too. Also, they couldn't use any fuel that left behind a lot of ash. The first engines used gases. By 1860, a successful engine that ran on gas (illuminating gas, not gasoline) was being sold.

However, storing and transporting a gas is a problem. So engineers began to try liquid fuels, like alcohol, kerosene, and gasoline. A liquid fuel would have to vaporize easily, and it would have to be available in great quantities. Remember that, up until this time, gasoline was an unwanted by-product in the manufacture of kerosene for lamps. Gasoline turned out to be the best compromise fuel.

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The Evolution of the Internal Combustion Engine

Put on the overhead transparency of the evolution of the internal combustion engine. Point out the progress in size and weight.

Homework Assignment

Ask students to fill out the worksheet on internal combustion engines.

Additional Activities

Field Trip

Arrange a field trip to an auto repair shop or to your high school auto repair class. Prepare for the visit by having students learn the functions of a few fundamental parts of most internal combustion engines: carburetor, sparkplug, cylinder, piston, valve.

Model Engines

Most schools have students whose hobby is building miniature, power-driven airplanes, boats, or cars. Invite one of these students to your class to demonstrate the operation of a model engine. In many models, the movement of the piston can be seen through an open port on the side of the cylinder.

Visible V-8

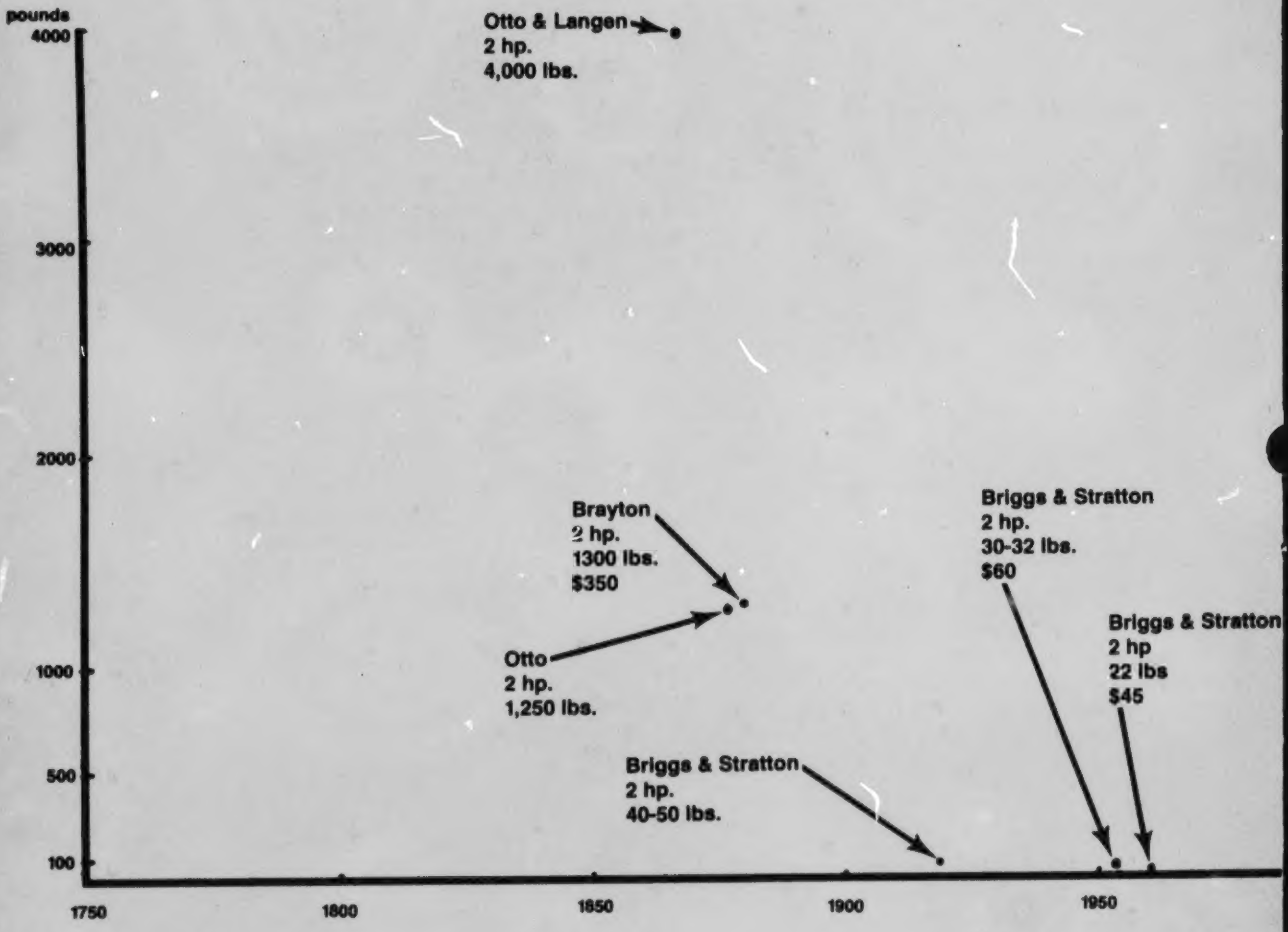
A kit is available (manufactured by Revell, $26.50) for building a clear plastic, working model of a V-8 auto engine. If any student in the school has built one of these, invite him or her to bring it in and show it to your class.

Projects for Independent Investigation

1. Investigate the difference between fuel injection and carburetion in an automobile engine. Make an oral report to the class.

2. Report to the class on the difference between a gasoline engine and a diesel engine.

3. Investigate the history of steam-powered automobiles. How well did they perform? What were their advantages and disadvantages? Give a brief talk to the class. As part of your talk, explain why you think the steam engine lost out to the gasoline engine in motor vehicles.


pounds
4000
3000
2000
1000
500
100
1750
1800
1850
1900
1950
Otto & Langen
2 hp.
4,000 lbs.
Brayton
2 hp.
1300 lbs.
$350
Otto
2 hp.
1,250 lbs.
Briggs & Stratton
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40-50 lbs.
Briggs & Stratton
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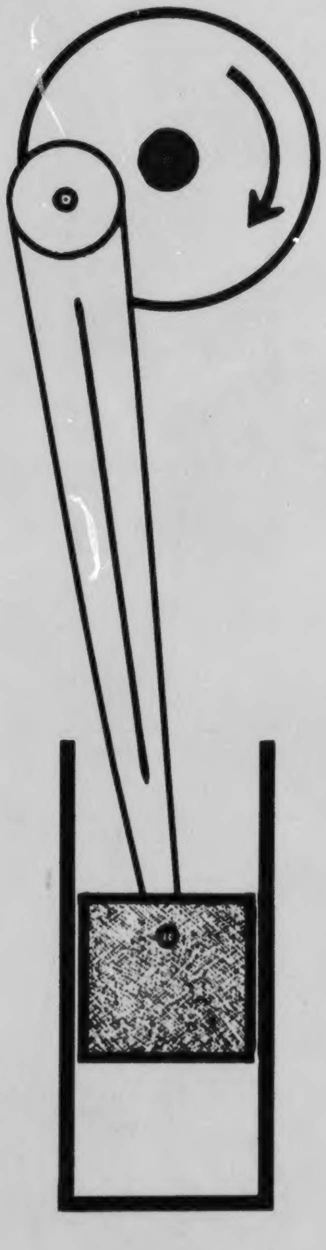
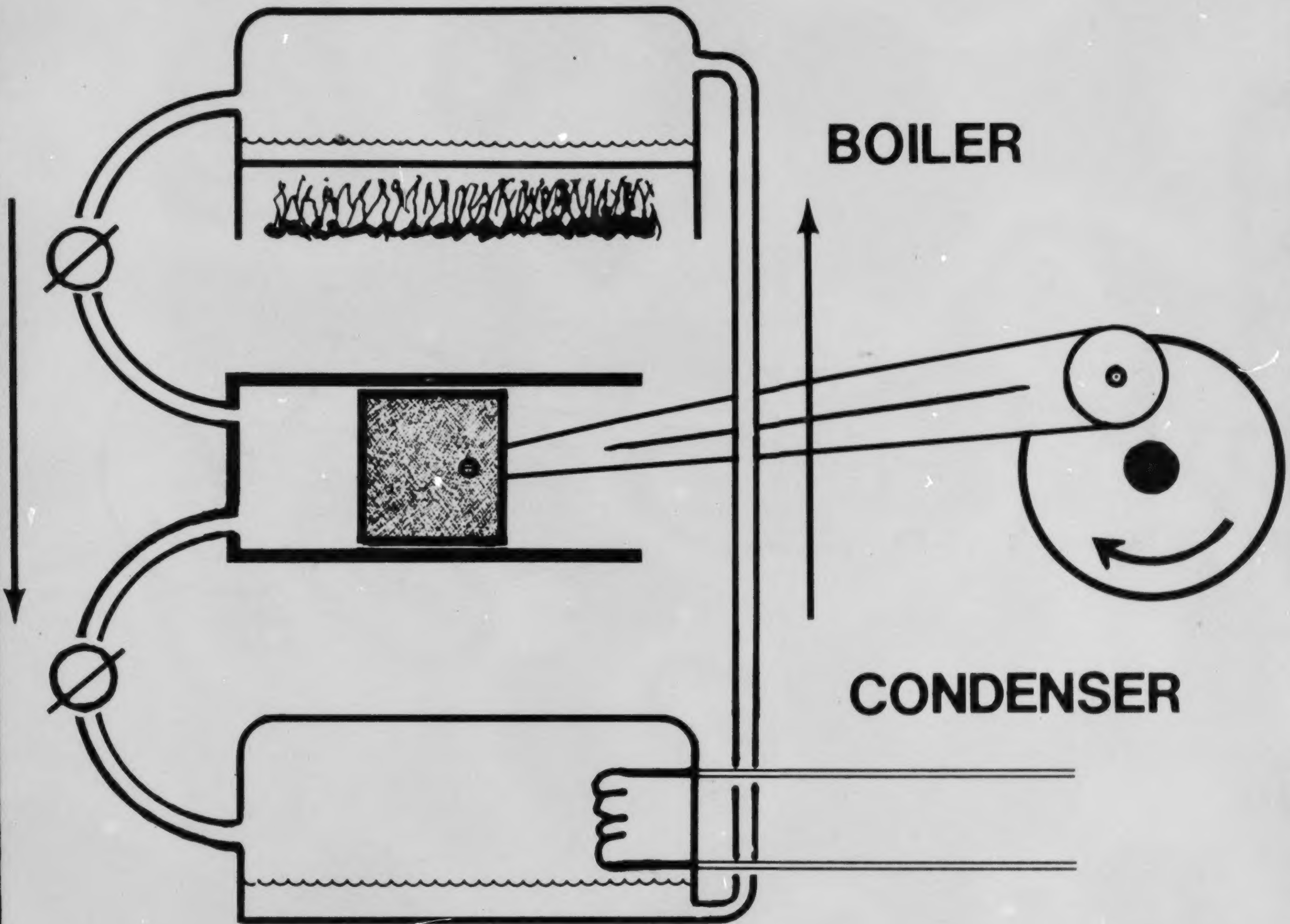
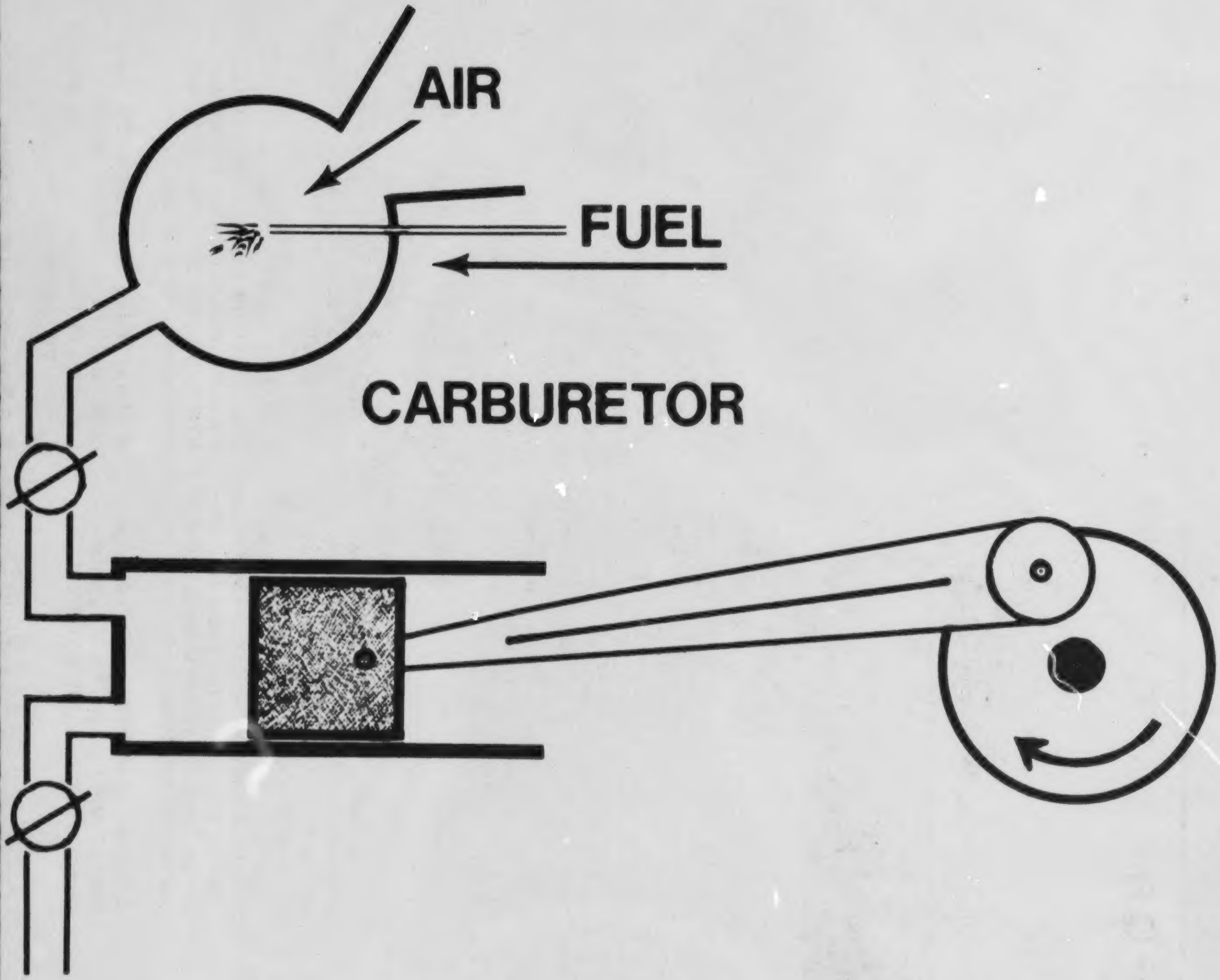
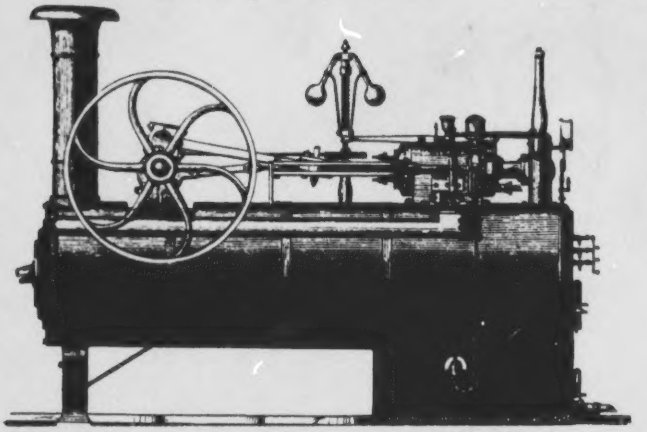
Briggs & Stratton
2 hp
22 lbs
$45




BOILER
CONDENSER


AIR
FUEL
CARBURETOR

PORTABLE STEAM ENGINES.



No.	Power. H. P.	Boiler. Fire Surface. Sq. Ft.	Cylinder. Diam. In.	Cylinder. St'ke. In.	Speed. Rev. per Min.	Weight. Pounds.	Price. Cash.
1	2	22	3	9	175	2,200	$300 00
2	2	40	3	9	175	2,350	365 00
3	2½	47	3½	9	175	2,500	385 00
4	3	44	4	10	150	2,700	425 00
5	4	50	4½	10	150	2,900	450 00
6	5	60	5	10	150	3,200	475 00
7	6	90	5½	10	175	3,700	575 00
8	7	97	6	10	175	3,900	600 00
9	8	100	7	10	175	4,500	675 00
10	12	139	8	12	175	5,800	840 00
11	15	161	9	12	175	6,500	950 00
12	20	286	10	18	125	10,300	1,300 00
13	25	308	11	18	125	11,500	1,400 00
14	30	357	12	18	125	13,000	1,550 00
15	35	432	14	18	125	15,000	2,000 00
16	40	510	16	18	125	17,000	2,300 00

These Engines are very compact and complete, having a feed-water Heater, Force-Pump, Regulator, Belt-Pulley, turned on the face, Steam-Gauge; in short, every thing necessary to set them in operation, on the introduction of water and fuel, (either wood or coal,) to the boiler, and applying a belt. No smoke-pipe is furnished with them, as it is bulky, liable to injury if sent unboxed, and expensive to box up. Eight, ten or twelve inch stove-pipe, of heavy English sheet iron, is all that is required, and that is to be had anywhere, in any length the location demands.

The Boilers are of best American iron, strong, well made, and supplied with fusible safety-plug; and warranted to bear a cold-water test pressure of 200 lbs. per square inch, and a constant working pressure of 120 lbs. They embrace the principles of the best modern locomotives, are well made, without finish for show, and are capable of working much above the power inserted in table. Extra finish at extra prices. Our No. 10, Extra Finish, can be seen at the Varnish and Paint Store of Stimson, Valentine & Co., No. 36 India Street, Boston.

The medium sizes, such as Nos. 5, 6, 8, 9, 10, 11 and 12 are always in progress, and can generally be finished to order in from three to six weeks.

☞ All Engines fired up and tried before they leave the shop, and warranted tight, safe, and in all respects ready for operation. Failing to give satisfaction, they will be taken back, and the money refunded.

A good strong running gear, arranged so as to be easily attached and detached at pleasure, will be supplied at from $125 to $225 extra—forming a useful wagon when separate.

Address, **J. C. HOADLEY, Lawrence, Mass.**

This advertisement by an American manufacturer of steam engines actually appeared in 1860. One dollar in 1860 could buy about as much as $8.70 could in 1979. Two horsepower is about the size of a big lawnmower engine. A Volkswagen "Beetle" engine puts out about 40 horsepower. Read the advertisement, and then answer the questions.

1. Would Model 16 fit in a Volkswagen Beetle? Why? Do you think a Beetle engine would be worth $20,000?

2. Would Model 1 fit on a lawnmower? Why? Do you think a lawnmower engine is worth $2,610?

3. Model 1 costs $300 and puts out 2 HP. That is $150 per horsepower. If you paid the same amount for each horsepower for Model 16 as you did for Model 1, how much would Model 16 cost?

4. Model 16 has twenty times the power of Model 1 (40 horsepower versus 2 horsepower). How many times the price is it? How many times the weight?

5. As the engine size decreases, why does the price decrease more slowly than the horsepower? Why does the weight decrease more slowly than the horsepower?

Using Portable Power

Lightweight, low-cost internal combustion engines are in use all around us. Automobiles are an obvious example. Some other uses aren't so obvious. Here is a list of some activities. For each activity, try to name as many machines as you can that are used in that activity and that incorporate an internal combustion engine.

Sport fishing:

Farming:

Firefighting:

Gardening:

Model building:

Warfare:

Are We Really Running Out of Oil?

To know when we'll "run out" of oil, we need to estimate two things: how fast we use it, and how much we'll be able to get from the earth. (Of course, how much we get also depends on how much we are willing to spend getting it.)

The following selection is taken from the conclusion of *Giant Oil Fields and World Oil Resources*, a study by Richard Nehring for the Central Intelligence Agency. (Report R-2284-CIA, Santa Monica, CA: the Rand Corporation, 1978). This public document provides one of the most authoritative estimates available of how much oil there really is.

The footnotes called out by letters are Mr. Nehring's; those called out by numbers are additional explanations that we have added.

Ultimate World Oil Resources

The ultimate recoverable conventional crude oil resources of the world are estimated to be 1700 to 2300 billion barrels.[a] This includes 335 billion barrels that had already been produced by the end of 1975, 676 billion barrels of proved and probable reserves, from 263 to 555 billion barrels to be added from future discoveries, and from 420 to 730 billion barrels to be added from further development of and additional recovery from known fields. Additional recovery is thus projected to provide 57% to 61% of future additions.

The range of 1700 to 2300 billion barrels incorporates most of the major uncertainties in world oil resource estimation, assuming that the exploration of unexplored provinces will yield results basically analogous to those in the explored provinces[1] and that future development and recovery worldwide will be basically comparable to that likely to be achieved in the most highly developed fields today. If the ultimate amount proves to be outside this range, one or more non-analogous events or developments will have to occur.

Ultimate conventional crude oil resources will be less that 1700 billion barrels only if there is a sharp drop-off in discoveries of giant and large fields (most likely from a lack of new major provinces), and if additional recovery efforts yield poor results, even at significantly higher prices. For ultimate conventional crude oil resources to be more than 2300 billion barrels, one of the following developments will have to occur:

(1) proportionately more of the unexplored provinces prove to be major provinces than have the explored provinces;

(2) a few new major provinces, larger than any known province other than the Arabian-Iranian Basin (i.e., 50 to 100 billion barrels and several super-giants each), will be opened up;

(3) one or more Ghawar-size fields will be discovered; or

(4) additional recovery efforts, particularly in the Middle East, prove to be highly successful.

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[a] Although the components do not quite equal the totals, the estimate is rounded off because the uncertainty in estimation does not permit any meaningful numbers beyond two significant digits. Readers familiar with recent estimates of world oil resources will notice that the midpoint of the range coincides with the "consensus" estimate of 2000 billion barrels. Contrary to appearances, the agreement is purely fortuitous, for the totals presented here were not determined until the disaggregated analysis was completed.

[1] "Province" is the word geologists use to describe a geographic area sharing the same geological structure. The author is assuming that no "freakish" geology will be found in areas not yet explored. A "non-analogous event" means a discovery unlike anything found so far.

None of these developments are impossible. It appears to be most unlikely, however, that ultimate conventional oil resources would be less than 1700 billion barrels. The known prospects in the current producing provinces and the record of continued giant field discoveries since 1975 suggest that a very sharp drop-off in discoveries is improbable. The prospects for secondary recovery alone, a technique that has been used worldwide in many geologic circumstances, are substantial, particularly in the Middle East.

Reducing the uncertainty at the high end of the estimate cannot be so easily substantiated. Each of the three logical possibilities for future major discoveries would be a non-analogous event, given the past history of exploration. They are excluded from the range estimated here because they are non-analogous and because a sketchy survey of the known geology of the unexplored and lightly explored provinces did not indicate a highly promising potential. However, because exploratory surprises do occur, the most recent being the opening up of the Reforma area in Mexico, each of these possiblilities should be kept in mind as exploration continues. Further exploratory activity, particularly in the next 10 to 20 years, will provide the information to indicate whether any of them are realistic. Very successful recovery efforts resulting from high rates of investment and improvements in recovery technology appear to have a reasonable probability of occurring. They are excluded from the range estimated here because they fall outside the realm of present experience. If they do occur, their primary effect will be on oil availability in the next century.

The distribution by field size[2] of ultimate crude oil resources is expected to change only slightly from the present distribution. (An approximate ultimate distribution is provided in Table 5.1[b].) Super-giant fields will become somewhat less important: large non-giant fields will become somewhat more important. Other giant, large non-giant, and other non-giant fields are predicted to comprise a greater proportion of future discoveries than they have in the past. The share of additional recovery from super-giant fields — known, potential, and prospective — is predicted to be greater than the current proportion of known recoverable resources in super-giant fields, primarily because of additional recovery from the super-giant fields of the Middle East.

Table 5.1
Estimated Distribution of Recoverable Oil Resources of the World by Field Size

Field Size	Number	Amount (In billions of barrels)
Super-giants	45-55	825-1065
Other giants	475-550	475-635
Large non-giants	1000-1400	200-350
Other non-giants	No estimate	200-250
Total		1700-2300

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[2] The author classifies fields by size into the following groups: super-giant fields, at least 5 billion barrels of known recoverable oil; giant oil fields, at least 500 million barrels of known recoverable oil; larger non-giants, 500-100 million barrels; other, everything less than 100 million barrels.

[b] The number of fields in each category reflects both new discoveries and transfers from other categories because of reserve growth.

The geographic distribution by region (including the adjacent continental margins) of ultimate conventional world crude oil resources is projected to change only slightly. (An approximate distribution by region is provided in Table 5.2) Despite the high promise of the Reforma area of Mexico, the importance of North America is projected to decline slightly. The overall proportions in South America, Eastern Europe/the Soviet Union, Africa, and the Middle East are expected to remain basically unchanged. The respective shares in Western Europe and Asia/Oceania (including Antarctica) are expected to increase slightly. Considering that these disaggregated projections are somewhat more uncertain than the range of the total, these differences are basically insignificant.

The geographic distribution projected here differs significantly from those of most other estimates with similar totals. In particular, other estimates[c] project considerably more for the Soviet Union (twice as much in some cases), somewhat more for Western Europe and Asia/Oceania, and much less for the Middle East. The estimates for North America, South America, and Africa in Table 5.2 and in other estimates are roughly similar, given the prevailing uncertainty. The primary reasons for these differences are (1) other estimates have not explicitly incorporated an assessment of the additional recovery potential of the Middle East, and (2) other estimates overstate the oil potential of the relatively unexplored provinces in the Soviet Union, not taking into account the fact that those that are beginning to be explored are turning out to be principally gas provinces.

Table 5.2
Estimated Ultimate Conventional World Crude Oil Resources by Region
(In billions of barrels)

Region	Known	Potential	Total
North America	179.8	100-200	280-380
South America	68.4	52-92	120-160
Western Europe	24.6	24-45	50-70
Eastern Europe/ Soviet Union	102.4	63-123	165-225
Africa	75.6	45-94	120-170
Middle East	509.9	350-630	860-1140
Asia/Oceania	50.8	54-104	105-155
Total	1011.5	688-1288	1700-2300

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[c] For example, Moody and Esser, "An Estimate of the World's Recoverable Crude Oil Resource" and the consensus estimate published by the Conservation Commission World Energy Conference, Report on Oil Resources.

Oil Resources and Oil Availability

The preceding review of world oil resources suggests that there will ultimately be 1700 to 2300 billion barrels of oil recovered from conventional crude oil fields. This range, less cumulative production, is equivalent to 60 or 90 years of world consumption at current rates. However, it does not include the hundreds of billions of barrels that could become available from heavy oil (tar) sand and oil shale deposits.

Several factors will determine the rate at which the ultimate resource will become and be available. Because the ultimate resource is concentrated in giant and super-giant fields, the factors determining world oil availability essentially revolve around giant fields: the rate at which they can and will be discovered, the rate at which they will be developed and produced, and their characteristics and economics.

For many of the Arctic and oceanic provinces, the necessary exploration or production technology is not yet available and is unlikely to be so for at least another decade. The technology necessary for exploration and production offshore in Arctic regions (except for shallow waters) is currently in the conceptual and developmental stages in the United State and Canada. Its application in the Soviet Union is in the even more distant future. Although exploratory drilling is now possible in waters 300 to 1500 meters deep, the technology for production in waters of this depth is still in the conceptual and developmental stages. Thus, even if giant fields are discovered in some of the most promising remaining unexplored provinces, production is not likely to be mechanically possible before 1990. In other areas, such as the off-shore areas of China, the necessary technology for exploration and production exists, but may not be employed rapidly for a number of political reasons (although there are recent indications that Chinese oil policy may be moving toward a more rapid development). The implication of the unavailability and the lack of full utilization of the necessary technology is that world oil availability between now and at least 1990 will be determined almost entirely by the availability of oil from known and yet-to-be discovered fields in known producing provinces.

Because production between now and 1990 will come almost entirely from the known producing provinces, near- and medium-term oil availability will depend primarily on the production policies of the OPEC countries. The current world potential for higher production is concentrated in these countries, particularly Abu Dhabi, Iraq, Kuwait, and Saudi Arabia. The extent to which it will be developed and used depends, first, on whether these countries will undertake or permit the necessary investment in additional productive capacity, the cost of which in many cases will be an order of magnitude[3] or more higher than most of the capacity developed in these countries to date (but one that still provides a complete payback on investment at present world oil prices within one to two years at most).

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[3] "An order of magnitude" — different by a factor of ten; the difference between tens and hundreds, or between thousands and tens of thousands.

A key factor is the point at which investments in secondary and enhanced recovery operations in giant fields will become desirable in the major exporting countries. Second, the development of additional capacity depends on the extent to which these countries, particularly Saudi Arabia and Abu Dhabi, will want to determine the world crude oil prices. The availability of excess capacity, which they essentially control, will be the principal factor in determining the rate of increase in world oil prices. It will not, however, be the only factor in determining world oil prices. The potential that could be discovered and developed outside the OPEC countries is sufficient to constrain prices for the next 10 to 15 years, assuming that demand does not grow by more than 1.0% to 1.5% annually. Finally, additional capacity will depend on their decisions as to the rate of depletion that they consider to be desirable for their long-run economic future. Oil production in all of these countries is concentrated in a handful of giant and super-giant fields. If no major fields or even if only a few more major fields are discovered in each, these countries will know that the rapid depletion of their existing fields means the depletion of their principal natural economic asset. Their decisions to increase production capacity are thus inescapably decisions about their long-run pattern of economic development.

Future oil availability will also be determined by the economic returns available to both producers and refiners. The period in which incremental oil production capacity could be added very cheaply, a period that was synonymous with the discovery and initial development of the super-giants, is past. Future increments to capacity will come from fields discovered in expensive environments, from fields with lower well productivity, from smaller fields, or from the application of secondary and enhanced recovery. In those countries where the investment in incremental capacity is made by the oil companies rather than by the government, the returns to companies will have to be sufficient if the necessary investments are to be made. Uncertainty, especially about future taxes and royalties, could be a major deterrent to further investment. Moreover, additional investments will be required in the refinery sector. A considerable amount of the undeveloped known potential productive capacity of the world is in heavy, high-sulfer oil fields. Altering existing refinery capacity to process a growing proportion of crude oils of this type will require major investments (although the investment per barrel of capacity is generally substantially less than the investment per daily barrel of enhanced oil recovery capacity). The refinery investment problem is magnified by the trends in the major oil-consuming countries toward implementing stricter sulfur emission standards and toward deemphasizing the use of oil in industrial boilers and for electrical generation. Producing a higher proportion of lighter, lower sulfur products from increasingly heavier, higher sulfur crude oils will require major changes in existing world capacity.

Depletion of Finite Resources

We were introduced to this activity in a workshop by Janis Philbin, formerly Program Assistant to the Energy, Food, and You Project, Washington State Office of Public Instruction.

Objectives

This lesson contributes to students' understanding of the following concepts:

As more of a resource is extracted, it becomes more difficult to extract what remains.

Technological innovation can change the availability of a resource.

Extraction of a resource often inflicts environmental damage; energy is needed for the process of re-creating a livable environment.

The resource that is most plentiful is not necessarily the easiest to get.

Format of the Lesson

(Before class, preparation of beads and cornmeal)

Divide class into teams

Scatter beads

Explain rules

Play several rounds

Discuss activity

Discuss meaning of results

Materials Needed

chalkboard

beads four colors, about two tablespoons each. These are the beads used by Boy Scouts in making Indian beadwork; they can be purchased at hobby stores for about 60¢ a color for a tube full. Reusable, though some will be lost each year. If you have no carpeting in your school, you can use short grain white rice dyed with undiluted food coloring and dried in the oven on a cookie sheet. The danger is that, if they become moist, they will leave batik patterns on anything they come in contact with.

cornmeal half a cup.

paper cups five.

Preparing the Beads

Before class, in a cup or other open container, make a mixture of differing quantities of four colors of beads plus one-half cup of cornmeal. The larger the class, the more beads you will need. An all-colors total of 200 beads per student is about right. For example, you could put in three tablespoons of blue beads, a tablespoon of red, five tablespoons of cornmeal, and so on. Set aside out of sight.

Setting Up the Activity

Ask the students to count off by fives, thus forming five teams scattered all over the room.

Appoint team leaders who are good at addition and give each leader a paper cup.

On the chalkboard, make a list of colors and assign each team a color (make one team cornmeal), and note the name of the leader. This will later form the left-hand side of the diagram shown below.

Take the cup of beads and fling the bead mixture out into the room, toward the ceiling (hang on to the cup)!

This act never fails to get the students' attention.

Explaining the Rules

Tell the class they are going to play a game, and these are the rules:

1) When I say "go," you have exactly one minute to pick up beads of your color — or grains of cornmeal. Stop immediately when I say "stop."

2) "After I say 'stop,' count how many beads you have picked up. Then give the beads to your team leader and tell her or him how many you had."

3) Team leaders, add up your team's total score. Tell me what it is and I will enter in on the chalkboard. Leave the picked-up beads and cornmeal in this cup on my desk.

Playing

Say "go!" Begin timing. Stop the scavenging after one minute.

When students have finished counting, enter the results on the chalkboard. Label the column "first minute" and rule a second column next to it. Label that column "second minute."

Tell the class we will do it again to see what changes.

Continue for as many rounds as are appropriate for the number of beads you tossed out, the difficulty of finding them, and the interest of the students. The final chart may look something like this.

	First Minute	Second Minute	Third Minute	Fourth Minute	Fifth Minute	?
1. red						
2. blue						
3. white						
4. green						
5. cornmeal						

22[illegible]

Discussing the Activity: A Sequence of Questions

Predict how many beads we would get if we did another minute's search.

Which took more effort to find, the first bead you picked up or the last bead? Why? (ANS: Last.)

Do you think we would ever find all the beads? (ANS: Maybe not. The last ones will be very time-consuming to find.)

In most classes, more beads are collected in the second minute than in the first, since by then students have figured out where most of the beads went and have become more adept at picking them up. If this happened in your class, ask why the numbers in the second column are bigger than those in the first.

There was far more cornmeal than anything else. Why didn't we pick up more of it than anything else? (ANS: Too hard to pick up compared to beads.)

Can you think of anything we might do to get more cornmeal? (ANS: Get a vacuum cleaner.)

Discussing the Implications: Comparison with Extraction of Resources

In what ways are the beads like the earth's supply of petroleum, copper, or coal?

Would you expect it to require more effort to get the first million tons of coal or the "last" million? Which costs more to get, the second million tons or the next-to-the-last million tons? Will we ever get all the coal or oil? Why not? (ANS: Because it would be so difficult to do, and hence so expensive, that it wouldn't be worth doing.)

Can new technologies change the relative importance of sources? How does the cornmeal resemble a very diffuse though plentiful energy source, like sunlight? How does it resemble tertiary recovery?

In what ways isn't this exercise really like extracting minerals? Was there a changing incentive to get the beads? Is there in extracting minerals? What is it? (ANS: Rising prices.)

Lastly, ask the students to look around the room. Has our "extracting minerals" wrought environmental havoc? Can we put it back to rights? Does it take energy to do so?

Have the students straighten out the room, thus demonstrating that reclamation does require energy, and providing a natural close for the period.

Can Heat Do Work?

Objectives

This lesson contributes to students' understanding of the following concepts:

Even "primitive" societies need much of of their energy in the form of mechanical energy.

For thousands of years, people searched for a practical way of changing heat to mechanical energy.

Materials Needed

flask with one-hole stopper

glass tube

ring stand

heat source such as a lab burner or can of Sterno.

To make the aeolipyle:

tin can square, with a press-fit lid, the sort tea comes in (e.g., Twinings).

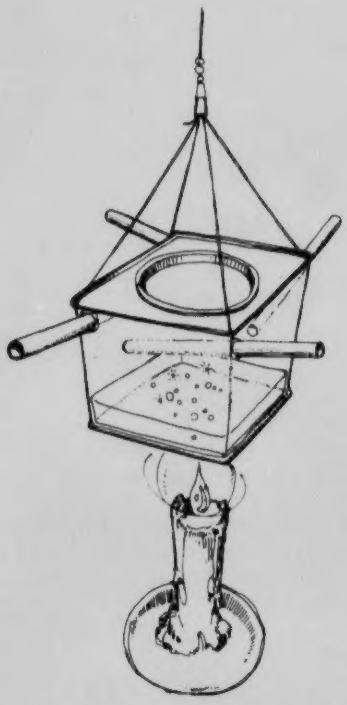
silicone glue-sealer about $3.20 for 83 mL.

plastic drinking straws four. The kind used as stirrers for alcoholic beverages work best; they have a smaller inner diameter, which increases the velocity of the escaping gas. Plastic straws may melt unless great care is taken when using the apparatus. Metal tubes can be substituted.

ball-bearing swivel such as Sampo No. 3SB, available from sporting goods stores at three for about $2.50.

string

To Construct the Apparatus



Please refer to the illustration. To construct the apparatus, punch a hole in each of the four sides of the can, near the upper right corner of each side. A nail with the same outside diameter as the straw can be used for this. Punch a second, much smaller hole through each corner of the top of the can. (If you wish, the holes can be made by drilling.)

Using silicone glue-sealer, cement the straws into the can. When you push the straw through the hole, tilt it so that it is visible through the top of the can, and squirt a dab of glue onto the straw about a centimeter from its end. Then push the straw against the side of the can, keeping the end of the straw inside the can as high in the can as possible, so that steam, and not water, will escape through it. Seal the opening around the straw with more glue. Put all four straws into the tin this way.

Suspend the can from a swivel by threading string or fishing line through the holes in the corners, as shown in the drawing. These holes will probably also have penetrated the can, so seal them with a dab of sealant as you did the holes through which the straws were put.

Notice that this apparatus has a built-in safety valve: the press-fit lid, and the silicone sealer on the other holes.

A more durable apparatus can be made by soldering metal tubes to the can.

Establishing the Problem: Getting Mechanical Energy

Review that, thousands of years ago, people used fuel to keep warm and to make things like pottery and metal tools. Ask the class for examples of how people did these things.

Ask the class what other activities people needed energy for thousands of years ago. (ANS: They needed energy to plant crops, build houses, etc.) If you get no response, ask how people got fed, sheltered, clothed.

What kind of energy are we describing? (ANS: Mechanical energy, motion.)

So, people needed mechanical energy. But just about the only source of mechanical energy back then was muscle; human muscle or animal muscle.

Some people thought there might be a way of getting mechanical energy out of a fire. Let's look at an idea we find in a book written in the 1st century A.D. by a man named Hero of Alexander.

Demonstration: Heat to Motion

Hero might have begun by observing something like this:

Boil some water in a flask with a one-hole stopper and tube. When steam begins to escape from the tube, ask the class what observations they can make. If necessary, prompt:

Is anything moving? (ANS: The boiling water, the steam.)

So, we've found that we can change heat into motion by boiling water. However, it doesn't look like a way of getting useful mechanical energy, does it? But Hero had an idea.

The Aeolipyle

CAUTION: You do not want the apparatus to spray the class with boiling water. To prevent the boiling water from reaching the level of the straws,

1) Fill the metal can no more than ⅓ full of water, and

2) Do not apply an excess of heat. When the water begins boiling, either reduce the flame or raise the can until boiling is just adequate to maintain rotation.

Suspend the can over a burner, using a ring stand.

Ask the class what makes the can rotate.

Is the rotation very powerful? Try stopping the rotation with a stick, from above.

Ask the students if they think we could use the device to do useful work. Most will agree that this device, as it is, could not produce useful work.

Hero's gadget works on the same principle as a rocket. It did not develop into a useful engine for doing work; in fact, almost 1,800 years went by before people succeeded in making a reliable, powerful engine that changed heat into mechanical energy, and it worked on an entirely different principle. But the important thing is that almost 2,000 years ago people knew that the energy from a burning fuel could be converted to work, they just couldn't find a practical way of doing it.

Projects for Independent Investigation

1. Design an engine that would use the force of escaping steam, like Hero's, but would have some way of taking the energy off on a rotating shaft.

2. Describe to the class how another of Hero's inventions worked.

Unit Four

Energy from Nuclear Fission

Half-Life of Isotopes

Objectives

This lesson contributes to students' understanding of the following concepts:

Any radioactive material is constantly turning into another substance.

The rate of decay of a radioactive substance can be described by the length of time it takes half of any sample of the isotope to decay into some other isotope.

There is no way of predicting when an individual atom will decay.

Vocabulary

half-life

Format of the Lesson

Review nature of radioactive decay

Question: how to describe rate of decay

Graphing to discover the difference between constant and exponential

The pattern of radioactive decay

Introduce popcorn experiment

Perform popcorn experiment

Tally results

Discussing results

Conclusion

Materials Needed

chalkboard

boxes with smooth bottoms, like shoe boxes or fold-up shirt boxes, one per student.

popcorn about one pound of unpopped kernels of corn.

felt-tip pen

activity sheet **Half-Life,** one per student or group.

worksheet **Half-Life Graph,** one per student.

tally sheet one copy of form provided.

Reviewing Radioactive Decay

Review what the students have learned about radioactive decay, perhaps by asking the following sequence of questions.

How can you tell if a substance is radioactive? (ANS: It emits "rays.")

What is happening when a nucleus of a radioactive substance decays? (ANS: Its nucleus gives off something, particles and sometimes radiation.)

Why does a new element appear in a sample of radioactive material? (ANS: Number of protons in nucleus changes during decay.)

How is it possible to have two different forms of the same element, one of which is stable and the other unstable? (ANS: Different number of neutrons in the nucleus.)

Posing the Question

Since a radioactive isotope is constantly changing into something else, a very useful question to ask would be, how long will any piece of the isotope last before all the atoms in it have changed to something else? In other words, what is the rate at which the isotope decays?

A Familiar Example

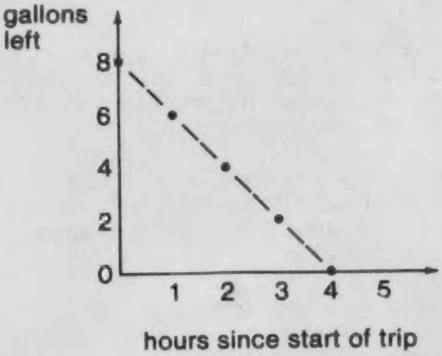
What do we mean by rate?

Let's look at a different example, one that involves a chemical change. We have a car that burns gasoline. Mostly, that's changing gasoline and oxygen to carbon dioxide and water.

Suppose we start a long trip with a tankful of gas, going at a steady 50 miles per hour. (Put figures on the board.) The car gets 25 miles per gallon. That means gasoline is disappearing at a rate of 2 gallons per hour.

$$\frac{\text{50 miles per hour}}{\text{25 miles per gallon}} = \text{2 gallons per hour}$$

Let's make a graph. (Do this roughly on the chalkboard.)



After one hour at 50 miles per hour, 25 miles per gallon, how much gasoline will we have used? (ANS: Two gallons.) How much will be left? (ANS: Six gallons.) (Make the appropriate dot.)

In the next hour? (ANS: Another two gallons.) Leaving how much? (ANS: Four gallons.) (Make the appropriate dot.)

In the third hour? (ANS: Another two gallons.)

OK, notice what's happening. We don't even have to calculate the next hour because we already have a picture of what's happening. All these points lie on a straight line. (Draw the line.) If we extend the line we see that all eight gallons will be gone at four hours.

Is this the way it goes with radioactive decay?

Well, as a matter of fact, it isn't.

The Pattern of Radioactive Decay

How can we tell how many atoms of a radioactive isotope are left — how much fuel is left in the gas tank, so to speak? We can do it with a Geiger counter or other instrument that measures radioactivity by measuring the number of alpha, beta, or gamma rays. The less radioactive substance there is, the weaker the radioactivity will be. (Provided, of course, that the daughter isotope isn't also radioactive.)

Suppose we have an imaginary radioactive substance, icecreamium-66. It decays into slop-66, which is stable.

(Make another graph, saving the gasoline one. Give yourself a good deal of space to the right, because this graph will have to go out to 10 hours.)

We call the radioactivity when we start 100%. After an hour, we measure again and find the radioactivity is only 50% as strong as it was before. Let's indicate that. (Make a dot.)

At 2 hours, we measure again, and we find 25% of the original radioactivity is left.

At 3 hours, 12½%.

At 4 hours, 6¼%.

Let's draw a line through the points.

Is this a straight line? (ANS: No.)

When will it hit zero and the icecreamium be all gone? (ANS: Not sure, or never.)

Maybe we should look at another imaginary isotope, barbarium-50. Remember, even though these are imaginary isotopes, this really is the way radioactive substances behave. The only reason I'm using imaginary isotopes is to have the numbers come out evenly.

Barbarium-50

Enter the points on the graph.

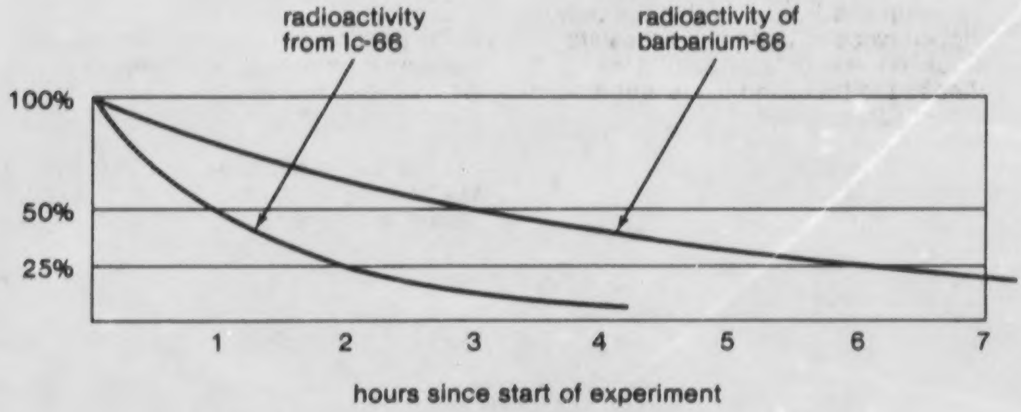
Time	Radioactivity
0 hour	100%
1 hour	79%
2 hours	63%
3 hours	50%
4 hours	40%
5 hours	31%
6 hours	25%
7 hours	20%

Can anyone predict when barbarium will hit 12½%? (ANS: Some students may already perceive that every three hours there is a halving of the activity, and so half of 25% will be reached in another 3 hours, or 9 hours in all. If not, ask leading questions. Call attention to the 50% line and ask how long that took. Then ask what half of fifty is and how much additional time it took to reach 25%. Eventually students will detect the pattern.)

If we know how long it takes half the substance to decay, then it will take that long again for half of what's left to decay. So a way of describing how fast a radioactive isotope decays is to give its "half-life" — the length of time it takes half of any sample to decay.

Why do radioactive substances behave this way? Basically, whether an atom is going to decay or not in the next second is a matter of chance. It might decay now, or it might not decay for another million years. The chances that an atom will decay in the next second are a lot greater with an isotope that has a short half-life like one second than with one with a long half-life like a million years.

Notice this isn't at all like a chemical reaction. At a hot enough temperature gasoline molecules will combine with oxygen atoms just as fast as we can bring them together. There won't be any free gasoline molecules left after a while, unless we run out of oxygen.



Introducing Experiment

To show how chance leads to half-lives, I'd like you to do an experiment. For atoms of a radioactive substance, we'll use kernels of popcorn, which we put in a box and shake. One side of the box is marked with an X, and we'll say the kernels that point to that side have decayed, and take them out. Then we'll graph our results.

Divide the class into groups of no more than three, if you plan to do this as a group experiment. Pass out the two sheets and the materials.

Performing the Experiment

Assist students in getting started.

As groups begin to finish, give them the tally sheet and ask them to enter the results. Select a student (preferably with a calculator) to add the columns while you discuss the experiment.

While the last groups are entering results, invite students to display their graphs.

Discuss the variation in graphs. Point out that this is not due to student's errors, but to the fact that the smaller a sample, the more variation. For example if we wanted to know how often coins come up heads, and each of us only flipped twice to find out, our results would be very different. But if we each flipped ten thousand times, our results would agree closely.

Use the figures from the class totals to construct a graph on the chalkboard or overhead projector.

Then discuss the following questions:

How many trials did it take to use up half the kernels? (ANS: Between 2 and 3.)

How may trials to use up half of the 50 that were left? (Usually occurs between the 4th and 5th trial.)

Notice that the curve from everyone's results is a lot smoother than any one group's curve.

In any sample there are millions and millions of atoms. Would you expect the decay curve measured experimentally to be smooth or not.

A Few Facts

Point out to the students that half-lives differ greatly. Share with them some examples from the following table.

Projects for Independent Investigation

1. Find out how half-life is used to estimate the ages of rocks OR of archeological finds. Make a report to the class.

2. Try plotting the results of the classes popcorn experiment on a sheet of graph paper whose vertical axis (ordinate) is logrithmic.

3. Look at the half-lives of U-235 and U-238. Why do think U-238 is commoner in nature.

Half-Lives of a Few Radioactive Isotopes

hydrogen-3 (tritium)	12.26 years
carbon-14	5730 years
oxygen-13	.0087 seconds
oxygen-14	71.0 seconds
oxygen-15	124 seconds
oxygen-19	29 seconds
oxygen-20	14 seconds
chlorine-36	310,000 years
potassium-40	1,280,000,000 years
vanadium-50	6,000,000,000,000,000 years
cobalt-60	5.26 years
zirconium-96	360,000,000,000,000,000 years
polonium-212	0.000000304 seconds
radon-216	.0000045 seconds
uranium-235	710,000,000 years
uranium-238	4,510,000,000 years
plutonium-244	80,000,000 years
plutonium-246	10.9 days

Half-Life

To do this activity, you need:

☐ a cardboard box with a cover and a smooth bottom

☐ kernels of popcorn

☐ a sheet of graph paper

Do you have everything you need?

Step One. Mark an X on one of the inside sides of the box.

Step Two. Count out exactly 100 kernels of corn and put them in the box.

Notice that each kernel of corn has a pointed end. When the corn is in the box, this pointed end will point to the four sides of the box. What do you think the chances are that any particular kernel will point to the side you marked "X"?

Step Three. Put the lid on the box and shake it thoroughly. Put the box back on the table and open it. Remove all the kernels that are pointing to the X-side. If you think some are pointing exactly at the X-side's corners, take half of those out.

Step Four. Count the number of kernels you took out. Enter the number on the graph sheet.

DO NOT PUT THE COUNTED KERNELS BACK.

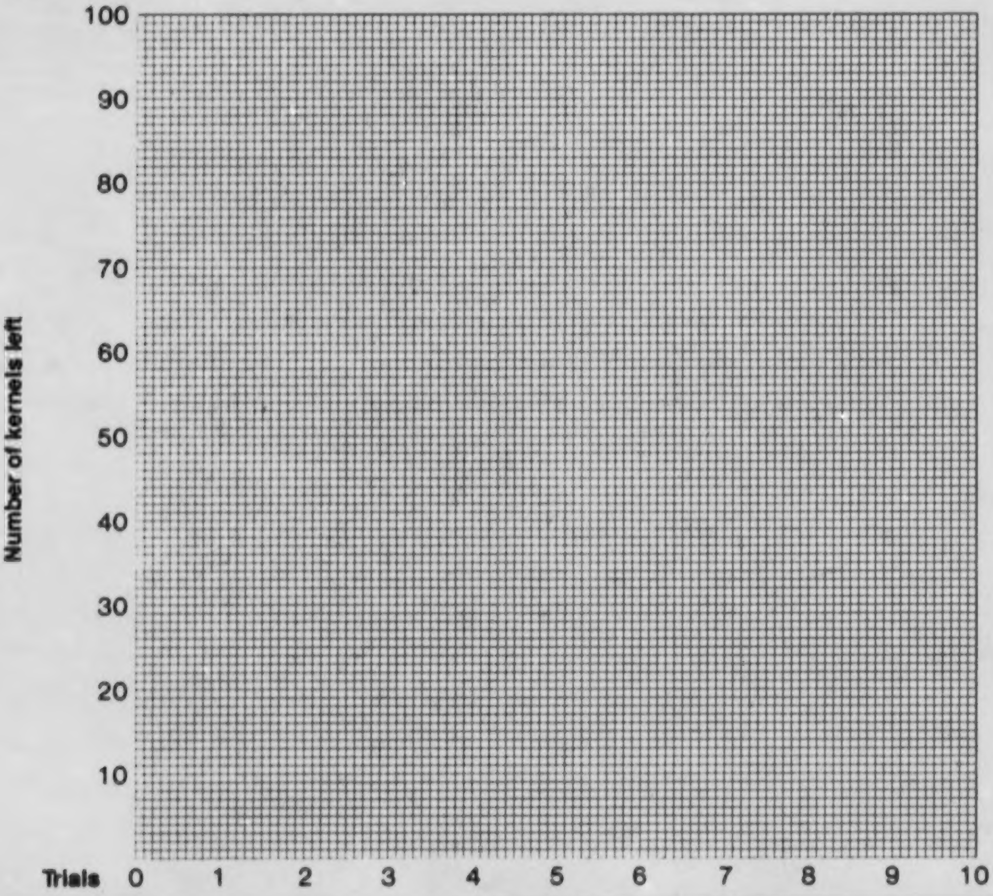
Repeat Steps Three and Four ten times. Then go on the the graph sheet.

Half-Life Graph

1. Figure out how many kernels were left in the box after each time you shook and counted.

Trial	Started with	Took out	Number left
1	100		
2			
3			
4			
5			
6			
7			
8			
9			
10			

2. Graph your results.



Tally Sheet

Trials

Students

↓	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
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21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
Total										

Energy from Fission

Objectives

This lesson contributes to students' understanding of the following concepts:

The fission of a uranium atom releases a large quantity of energy.

Mass can be converted to energy.

The energy released from nuclear fission is available as heat.

Format of the Lesson

This lesson is a chalk talk; its main subdivisions are outlined below. With some classes, you may want to perform the indicated calculations. In other classes it may be better just to skip ahead to the results.

Reviewing fission

The case of the missing mass

Converting mass to energy

How much energy in a kilogram?

In what form is the energy released?

Materials Needed

chalkboard

homework, one sheet per student

Reviewing Fission

Review that we've learned a nucleus of uranium-235 can be split into smaller fragments by a neutron. Use the chalkboard to show an equation for what happens.

This shows a nucleus of U-235 and a neutron combining to make a nucleus of uranium-236. The U-236 then fissions. On the right hand side, we've chosen one particular possible set of leftovers to show.

$${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{236}_{92}\text{U} \longrightarrow {}^{95}_{42}\text{Mo} + {}^{139}_{57}\text{La} + 7\,{}^{0}_{-1}\text{e} + 3\,{}^{1}_{0}\text{n}$$

There are lots of other reactions that might occur, but this is one of the most common, ending up in a nucleus of molybdenum (ma-LIB-da-nam), a nucleus of lanthanum (LAN-tha-nam), 7 electrons, and 2 neutrons. This isn't what the uranium nucleus splits into; those original fragments are radioactive and the molybdenum and lanthanum are the eventual products of their decay. The electrons come from that decay; not from the fission of the uranium-236.

See if the Equation Balances

Let's check to see if the equation balances by adding up the numbers of protons and neutrons. (Do the addition on the chalkboard, identifying the figures as you go.)

protons and neutrons in U-235	235
neutron that hit the U-235	1
total	236

Now let's see what we ended up with

protons and neutrons in molybdeum	95
protons and neutrons in lanthanum	139
the two leftover neutrons	2
	236

We started with 236 and we end up with 236, so the equation balances.

The Case of the Missing Mass

So far, we've been talking about the number of protons and neutrons. That is a pretty close approximation of the mass, since we know most of the mass of an atom is in the protons and neutrons of the nucleus. But as a matter of fact, we don't have to depend on counting protons and neutrons to determine the mass of the atom; we can actually measure it experimentally. We won't go into how you can do that, because it's complicated, so you'll just have to take my word that there is a way.

When we do this for the nuclei in this equation, we find out something really surprising.

For convenience, the unit we're going to use to measure the mass of the nuclei is the atomic mass unit, or amu. One atomic mass unit is defined as one-twelfth of the mass of an atom of carbon-12. So the mass of one proton or neutron is pretty close to one amu.

So, first let's add up the mass of what we started with. These are all masses determined by experiment. (Do the addition on the chalkboard.)

mass of the nucleus of U-235	235.0439 amu
mass of one neutron	1.0087 amu
	236.0526 amu

Now let's add up the mass of what we ended up with. (Ask students to identify products; you enter the mass on the board.)

mass of molybdenum nucleus	94.9058 amu
mass of lanthanum nucleus	138.9061 amu
mass of 7 electrons each .00055 amu	.0039 (rounded off)
mass of 2 neutrons	2.0174
making a grand total of	235.8332 amu

What do you notice about the two totals? (ANS: We started with more than we ended up with.)

Let's see how much mass we seem to have lost.

236.0526
-235.8332

.2194 amu (round it off to .219 amu)

Because amu are so unfamiliar, let's change this into grams.

1 amu = 1.6604×10^{-24} grams

Notice the exponential notation. I'm using this because this is such a very, very small mass. This part of the equation ("x 10^{-14}-") means multiply by 1 over ten with 24 zeros after it. So you can see it's very, very small.

.219 amu = $.219 \times 1.6604 \times 10^{-24}$ grams
= $.3636 \times 10^{-24}$ grams
(shifting the
decimal point) = 3.636×10^{-24} grams

This is a very, small difference, but a real difference. Part of the mass of the uranium nucleus we started with is missing!

Now, how can this be possible? You know matter doesn't just disappear. (At this point, students themselves may point out the interchangeability of matter and energy. If they do, compliment them and explain more fully.)

Einstein's Famous Equation

How many of you have every heard of this equation? (Put it on the board.)

$$E = mc^2$$

This is probably the world's most famous equation. It tells us that matter and energy are interchangeable, and how much matter is equal to how much energy. "c" is the speed of light. "m" is the mass of something sitting still. "E" is the amount of energy that mass is equivalent to.

Let's figure out how much energy the missing mass from the uranium nucleus would be equal to.

We will work in joules, so

energy in joules = (kilograms) x (speed of light in meters per second)^2

We are missing 3.636×10^{-25} grams. Let's change that to kilograms by dividing by a thousand. To do that, we need only to substract 3 from the exponent.

3.636×10^{-25} grams = 3.636×10^{-28} kilograms

The speed of light is 2.998×10^{8} meters per second, so

energy in joules = $3.636 \times 10^{-28} \times (2.998 \times 10^{8})^2$

squaring the speed of light (Notice that we only keep the four significant figures we started with. We could get lots of extra digits but they wouldn't mean a thing, because we only knew the speed with a precision of four significant digits in the first place.)

energy in joules = $3.636 \times 10^{-28} \times (8.988 \times 10^{16})$
= $3.636 \times 8.988 \times 10^{-28} \times 10^{16}$
= 32.680×10^{-12}

(rounding off) = 3.2×10^{-11} joules

Let's convert this to a more familiar unit, like calories.

1 joule = .239 calories
3.2×10^{-11} joules = 7.6×10^{-12} calories

How Much Energy in a Kilogram?

This doesn't look like a lot, does it? But remember, this is the energy from just one atom. In a kilogram of U-235 there will be about 26 x 10^{-24} atoms. If all of these atoms fissioned we would get (2.6 x 10^{24}) atoms x (7.6 x 10^{-12}) calories per fission or about 20 x 10^{-12} calories per kilograms of U-235.

In comparison, burning

one kg of coal gives –	6.9 x 10^{6} cal
one kg of gasoline –	10.5 x 10^{6} cal
one kg of natural gas –	13 x 10^{6} cal
one kg of wood –	3.3 x 10^{6} cal

So we see that you could get about 10^{6}, or a million times more energy from the fission of a kilogram of U-235 than from the combustion of fuels. In actual practice, however, we can't get this much energy from fission — and, do we get the energy in a useful form?

In What Form is the Energy Released

Here are some ways the energy of fission is released.

energy of motion of new nuclei	82%
energy of motion of neutrons	2%
gamma rays	3%
Beta particles (from decay of fission fragments)	3%
gamma rays (from decay of fission fragments)	3%
neutrinos (from decay of fission fragments)	5%

(doesn't add up to a 100% because of rounding off)

The neutrinos just escape into space. But everything else interacts with the surrounding atoms, and the eventual result is an increase in the random motion of surrounding atoms — in other words, an increase in heat. So basically heat is the form of energy we can get from nuclear fission — at least at the present stage of our knowledge.

Teacher Background

In this lesson, we used conversion of mass to energy to estimate the energy released in the fission of a single atom. But the amount of energy released can be estimated in several other ways, all of which are in good agreement.

For example, the concept of binding energy could be used. The mass of an atom, determined experimentally, is always less than the mass of the individual neutrons, protons, and electrons that could be assembled to make the atom. This "missing" mass represents the amount of energy which would be released if we could bind together protons, neutrons, and electrons to make the atom. To break the atom down into its components, we would have to supply this energy.

The binding energy of the uranium nucleus is smaller than the sum of the binding energies of the fission products; fission releases this difference.

A third way of estimating the energy released per fission is to calculate the electrical repulsion between the two positive fragments as they start to fly apart.

If You Were Nuclear-Powered...

Chances are that every day you eat about 3000 Calories (food Calories, or kilogram calories). That is equal to about 12 million joules.

Which chemical element in your food is most important in providing you with energy? Let's say carbon. Your body gets energy by oxidizing carbohydrates.

But suppose your body could get energy by converting mass (of carbon atoms) to energy. How many carbon atoms per day would you need?

A single carbon atom (carbon −12) has a mass of 2×10^{-26} kilograms. Calculate how many of these atoms you would need to convert to energy to equal the 12 million joules you get each day from food. Part of the calculation has been done for you; complete it by filling in the boxes.

1. How much energy from one carbon atom?

$$E = mc^2$$

energy in joules in one carbon atom = (mass of 1 carbon−12 atom in kg) x (speed of light in meters per second)^2

= (____ $\times 10^{-26}$ kilograms) $\times$ (3×10^{8} meters per second)^2

= ____ $\times 10^{-26} \times 9 \times 10^{16}$

= ____ $\times 9 \times 10^{-26} \times 10^{16}$

= ____ $\times 10^{-10}$

II. How many atoms per day?

You need 12 million joules each day, (12×10^6), so

$$\text{number of atoms needed} = \frac{\text{joules you need per day}}{\text{joules from converting 1 carbon atom to energy}}$$

$$= \frac{12 \times 10^6}{\_\_\_\_ \times 10^{-10}}$$

$$= \frac{12}{\_\_\_\_} \times 10^6 \times 10^{10}$$

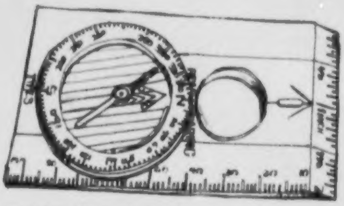
$$= \_\_\_\_ \times 10^{16}$$

I would need ______________________________ carbon atoms per day.
(This would make a piece so small you couldn't even see it, with a mass of about

$$\frac{1}{100{,}000{,}000{,}000 \text{ gram}}$$

Unit Five
Renewable Energy Sources

Getting Your Bearings



To do this activity, you will need a compass marked with degrees.

How many degrees in a full circle? ____________

How many degrees in a half of a circle? ____________

How many degrees in a quarter of a circle? ____________

Imagine you are standing facing the north, with your arms lifted to shoulder level and pointing in opposite directions.

What directions does your right hand point? ____________

What direction does your left hand point? ____________

What direction is to your back? ____________

Turn the compass so that the north end of the needle points to zero degrees. (If you know the magnetic error for your location, your teacher will show you how to correct it.) In taking bearings the rule is that north is always zero degrees.

What bearing will south be? ____________ degrees

What bearing will east be? ____________ degrees

What bearing will west be? ____________ degrees

What bearing will southwest be? ____________ degrees

How many degrees difference is there between east and south? ____________ degrees

How many degrees difference is there between south and west? ____________ degrees

How many degrees difference is there between west and south? ____________ degrees

How many degrees difference between west and east? ____________ degrees

Pick two objects in your classroom. Write their names below, and then measure their compass bearings from your seat. Subtract to find the angle between them.

Objects	Bearing
____________	____________ degrees
____________	____________ degrees

The size of the angle between the two objects is: ____________ degrees

Outside Work

How many degrees difference in bearing is there between the two tallest non-moveable things you can see from the school steps?

Thing One: ____________________ degrees

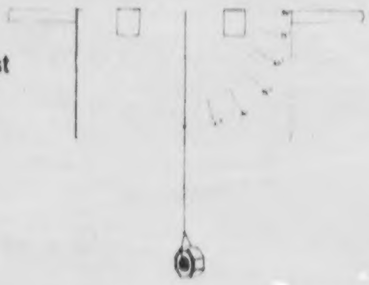
Thing Two: ____________________ degrees

Angle between them: ____________________ degrees

From the school flagpole, how many degrees difference in bearing are there between the easternmost and the westernmost edges of the school building? ____________________ degrees

Making an Astrolabe

To do this, you need:



☐ smooth dark string, such as a foot of buttonhole twist

☐ large nut (as in a nut and bolt)

☐ tape

☐ a drinking straw

☐ a protractor

☐ a sheet of stiff white paper – an index card is too flimsy. You may need to tape a sheet of white paper to a piece of heavy cardboard. A size of 8 cm by 15 cm inches is about right.

Procedure

Step One: Draw a line across the middle of the paper. Put a dot in the middle of the line. Take this dot as the center of a circle and using your protractor draw a semicircle and mark it off in degrees from ninety to zero, as shown in the drawing.

Step Two: Tie the nut to one end of a piece of string. Punch a small hole where the dot is and thread the string through it, so the nut hangs on the side of the cardboard where the degrees are. A good way to do this is to use a heavy sewing needle. Tie a knot on the other side of the cardboard, or use glue, so that the string doesn't slip through.

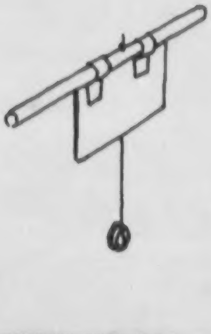
Step Three: Tape the drinking straw exactly along the line you first drew, so that it sticks out. Put your name on your instrument.

Using the Astrolabe

Look through the straw at some object in the sky, or just something tall.

NEVER LOOK DIRECTLY AT THE SUN!

Let the nut hang freely. While you are looking, clamp the string against the paper with your thumb. Then see where the hanging string crosses the degree markings. Read the number of degrees from the scale. That is the altitude of the object in degrees.



Questions

Suppose you were looking at the edge of the sea on a clear day. This is the horizon.

What altitude would it have? ________________ degrees.

What altitude would directly overhead be?
(This is called the zenith). ________________ degrees.

What altitude would half-way between
the horizon and the zenith be? ________________ degrees.

From your bedroom window, what object
was the greatest altitude? ________________ degrees.

Making a Shadow Graph

Objectives

This lesson contributes to students' understanding of the following ideas:

In the northern hemisphere, the sun is due south when it is highest in the sky.

Sun time and clock time do not exactly coincide.

The sun's altitude changes in a predictable way during a day.

Format of the Lesson

The activity in this lesson must be done outside on a sunny day during the morning, noon, and afternoon. Every student or group of students can make its own observations, or you can choose to do a demonstration for the whole class. If the students will not be using the equipment, it is somewhat easier to use a nail as the vertical rod, since it can be bent a little to adjust it to be perpendicular to the board. The straws, while less hazardous, can't be adjusted to a new angle to compensate for errors in drilling the holes.

In the classroom before the activity:

Discuss the value of recording observations of natural phenomena.

- Show the students a sample of the apparatus.
- Go over the directions on the worksheet.
- Arrange a time for conducting the observations.
- Construct the apparatus.

Materials Needed

boards one for each student. Wooden boards, pieces of plywood no less than 1/4" thick or, best of all, plastic beadboard ($1.75 for a 4' x 8' x 1" sheet) can be used. Beadboard or other usable insulating boards can often be scavenged as discards from building sites. Cardboard isn't thick enough to hold the straw in a vertical position. In the middle of the board, a hole should be drilled exactly perpendicular to the board and just the size of the straw. Use a drill press or a Portalign R (see your teacher).

straws as small in diameter as possible; one for each student. The round kind used as drink stirrers are best.

shadow graph form one sheet for each student. These can be reproduced from the master provided.

bubble-level one.

square or protractor one.

compass at least one.

tape one roll.

watch or clock at least one.

protractor one per student.

Observations:

In class, after the observations:

- Display all the sheets on the bulletin board.
- Discuss their meaning.

Following a Shadow

How can we record the direction of the sun as the day goes by? We shall try to do this with an instrument we'll construct. This instrument looks something like a sundial, but it doesn't tell time.

Note: You must begin this activity early in the day — no later than 10:00 a.m. and the earlier the better.

Step One: First, we need something flat with a vertical rod in the middle. Your teacher will have talked with you about this. We'll suppose it is a board with a short straw sticking straight up in the middle.

With a square or protractor, check to be sure the straw really is perpendicular to the board.

Your teacher will give you a sheet of paper with circles marked on it. On the paper is a line; the straw has to stick out above the surface of the board exactly as far as this line is long. Check to be sure that it does. Cut off some or add a new straw if necessary.

Step Two: Poke a small hole in the paper at the exact point where the crosshairs meet. This point is the center of the circles on the shadow graph paper.

The hole should be just big enough to let the straw through. Slide the paper over the straw and down onto the board. Center the straw exactly in the center of the crosshairs. Then tape the paper to the board. If your board is small, you may have to tear away some of the paper so that you can see some board to tape the paper to.

Step Three: Put the board outdoors in a place where it will not be in the shade at any time during the day. Using the compass, turn the board until the arrow marked south on the board points directly south.

(If your class has discussed magnetic declination, correct for it.)

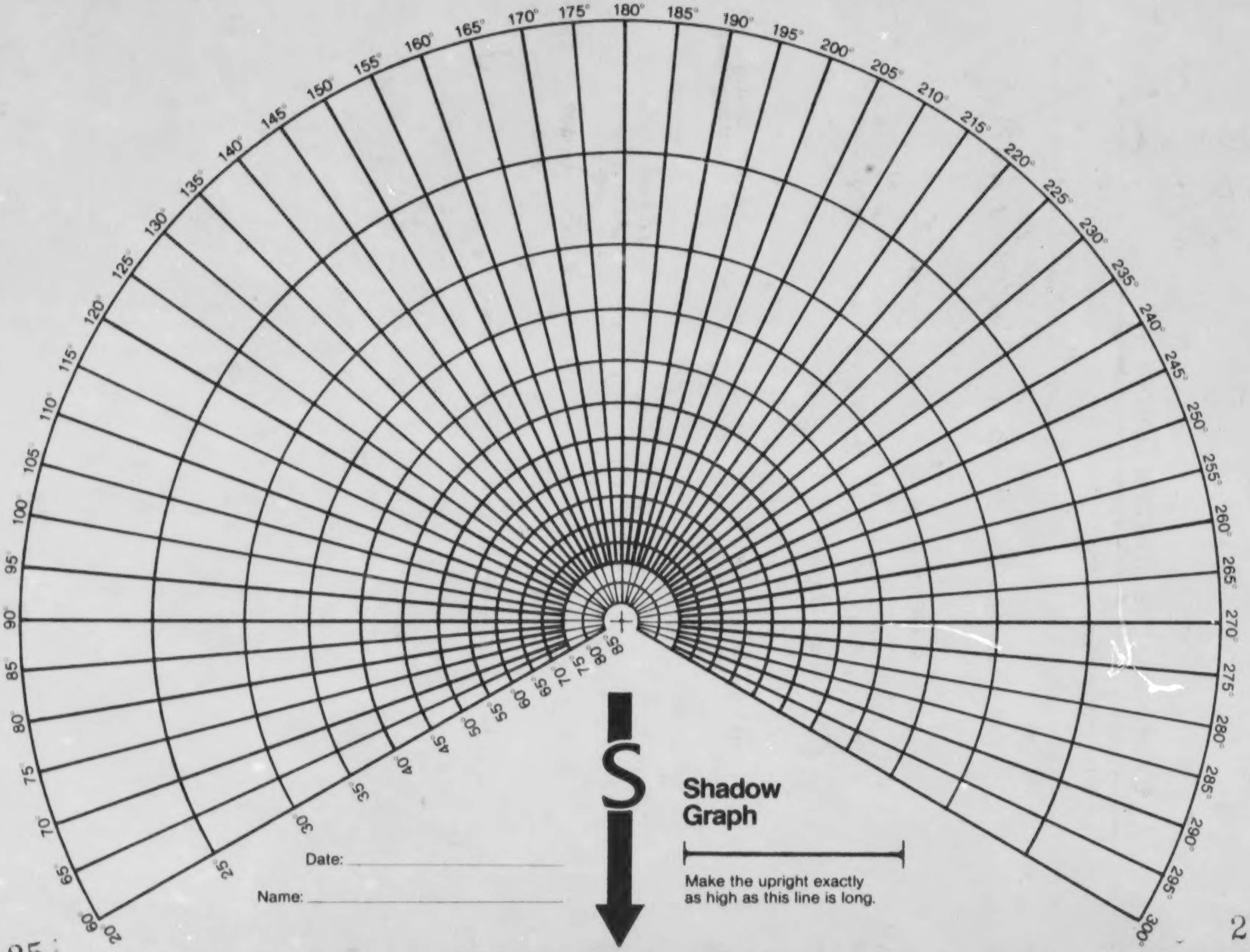
Now level the board level. If possible, use a bubble-level to make sure the board is level. Finally, brace the board as well as you can so it won't move accidentally during the day. (After bracing it, you may want to check again to be sure the arrow is pointing south and the board is still level.)

Step Four: The straw casts a shadow on the paper. Being very careful not to move the board, make a little dot at the end of the shadow. Draw a circle around it so you can see it, like this: (. 10:00 am). Next to the circle, write what time it is.

Step Five: Continue doing this as often as every fifteen minutes for the rest of the day. (Every hour is okay. Maybe you can do it between periods.)

Step Six: At the end of the day, sight along the straw at two different landmarks and make marks on the paper to show where the landmarks are. Write the name of the landmark next to the mark. Then remove the paper from the board.

Step Seven: Draw a smooth curve through all the dots you have made. Write your name and date on the paper and turn it in to your teacher.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Shadow Graph

Make the upright exactly as high as this line is long.

Date: ______________________

Name: ______________________

Examining the Shadow Graph

When and Where is Noon?

Answer these questions by studying the graph on which you recorded the moving shadow.

1. If the sun were directly overhead, where would the end of the shadow be?

____

Was the sun ever directly overhead on the day you made your graph? ____________

2. One way of defining noon is to say that it is the time when the sun is highest in the sky. This is called solar noon. As the suns gets higher in the sky, what happens to the length of the straw's shadow? ______________________________

____

3. Mark the place on your sheet where the end of the shadow was when the shadow was shortest. When the sun was in this position, it was solar noon. About what time was it then on the clock? ______________________________

Look at a map of time zones. What is the easternmost city where it is the same time as it is where you live? ______________________________

What is the farthest west city where it is the same time as it is where you live?

____

Can the sun be overhead at both these places at once?

____

Bearings

4. The sun is highest in the sky when it is due south. So when the shadow of a vertical stick is shortest, the shadow is running exactly north and south.

Draw a line on your shadow graph from the bottom of the straw to the point where the end of the shadow was when the shadow was shortest. This was the north-south line when you were making your observations.

Compare the line with the arrow pointing south, which is printed on the paper. You used this arrow to line up the shadow graph. After you set the paper, did the south arrow on it point exactly south?

If not, about how many degrees were you off? ______________________ degrees.

5. At sunrise and sunset, where do you think the end of the shadow would be?

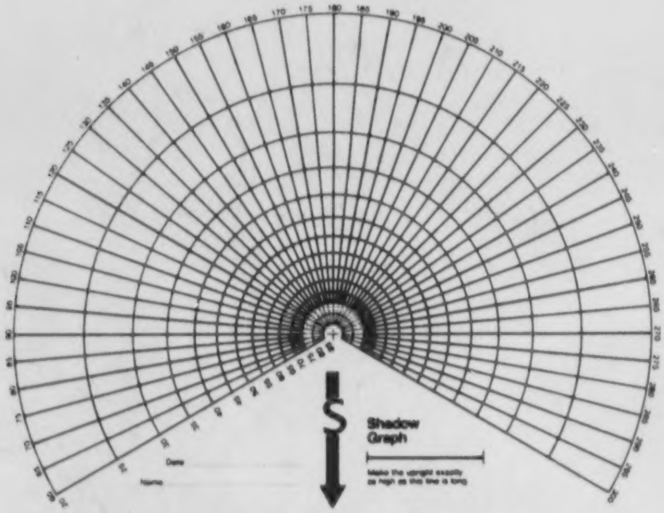
____

On the day you recorded the shadow, do you think the sun rose due east and set due west? ______________________ How could you measure the bearing of the rising or setting sun? ____

6. Here is a picture of the board, graph, and straw as if we were looking down on it. If the sun were exactly southeast, what would its compass bearing be?

(Ignore magnetic variation.) ______________________ degrees.

Draw the shadow the stick would make then. Draw in a sun due southwest.



Can you find a set of numbers on the shadow graph you made that indicates compass bearings? Label this set of numbers **Bearings**.

Altitude

7. Here is a picture of the board and straw from the side. On your shadow graph, measure the line that tells how high the straw is to be. Now measure the distance between the circle marked "45 degrees" and the bottom of the place where the straw went through the paper. How do the two measurements compare?____________________

____

On the drawing, mark where the end of the shadow would be when it was on the line marked "45 degrees."

On the drawing, draw a line that represents a ray of sunlight that just barely goes over the top of the straw. (The ray beneath it hits the straw and is blocked; only the top of the straw makes a shadow.)

Suppose there is an ant with an astrolabe standing on your shadow graph. He is standing at the end of the shadow of the straw, exactly on the 45° line. He is trying to measure the altitude of the sun. Using your protractor, help him out by measuring the angle between the sun and the ground.

What is the sun's altitude then? ______________________________

One of the sets of numbers on your shadow graph indicates the altitude of the sun. The numbers name a set of lines. When the end of the straw's shadow is on the lines, the number of the line is the sun's altitude. Can you find this set of numbers? Label the set **Altitude.**

One of the sets of lines is curved and one is straight. One represents altitude; one represents bearings. Draw lines to match them up.

Bearing	parts of circles
Altitude	straight lines

Creating a Sun Chart

By marking where the end of the straw's shadow was for a day, you made a record of the sun's movement.

But most people are not used to working with graph paper that has circles. People usually find graph paper with lines meeting at right angles is a lot more convenient. So in this exercise, you will transfer the record you made from the shadow graph to a regular rectangular graph.

To do this, you will need a piece of graph paper that your teacher will give you, your original shadow graph, and a sheet of plain ruled paper.

1. Look at the shadow graph. Each of the circles on it has a name. They are named in degrees. They show the altitude of the sun. Now look at the graph paper. The horizontal lines are named in degrees. We will use them to show the altitude of the sun. Find the line that represents the horizon, and trace over it.

2. Look at the shadow graph again. The lines radiating out from the center of the circles are named in degrees. They are the bearings. The line for South has the arrow we used to line the paper up with the compass. What bearing is due south?____________________degrees.
Now look at the new sheet of graph paper. The vertical lines are named in degrees. The heavier vertical line in the center of the paper is named **180 degrees.** This represents a direction. What direction? _______________All the other vertical lines also represents directions. Find southeast at 135 degrees. Find southwest at 225 degrees.

3. Now you are ready to move the information from one graph onto the other. Pick one of the dots you made on your shadow graph. A pair of numbers goes with this dot.

It indicates a sun altitude of ____degrees (taken from the circles).

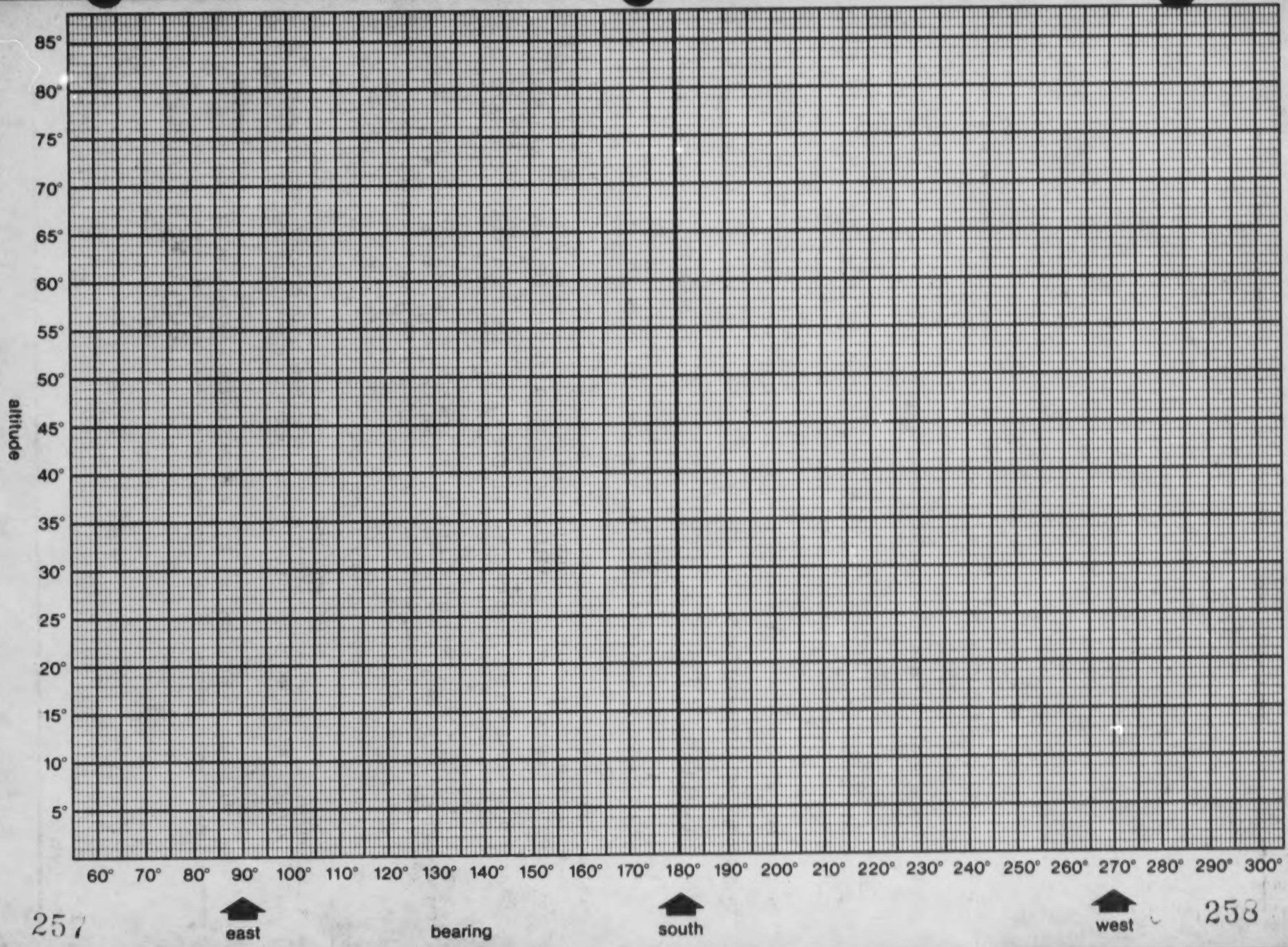
It indicates a sun bearing of __________________________________degrees (taken from the radiating lines).

Make a dot on your new paper that indicates the same altitude and bearing. Now put up your hand and ask your teacher to check your work.

4. When your first new dot is approved, make a table on a sheet of paper. Make three columns in the table: time, altitude, and bearing. Pick a dot on your shadow graph. Put its time, altitude, and bearing on the table. Then make a dot on the new graph that will mean the same as the dot on the shadow graph did.

5. When you have finished transferring all the dots you originally made to the new graph, draw a smooth line through the new dots.

Congratulations! You have made a sun chart showing the sun's movement on a single day of the year. You could have been royal astronomer in ancient Egypt or Mexico!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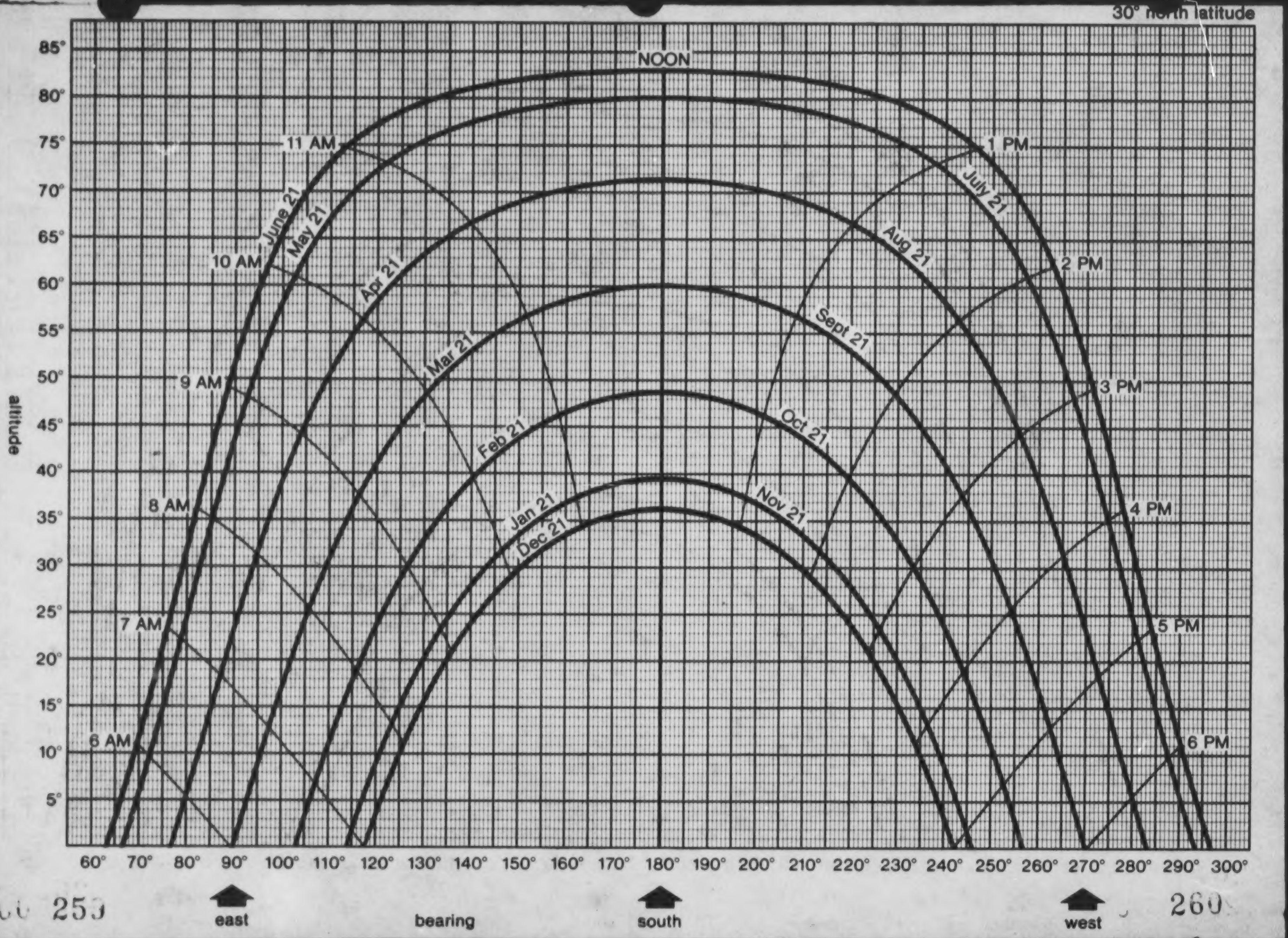
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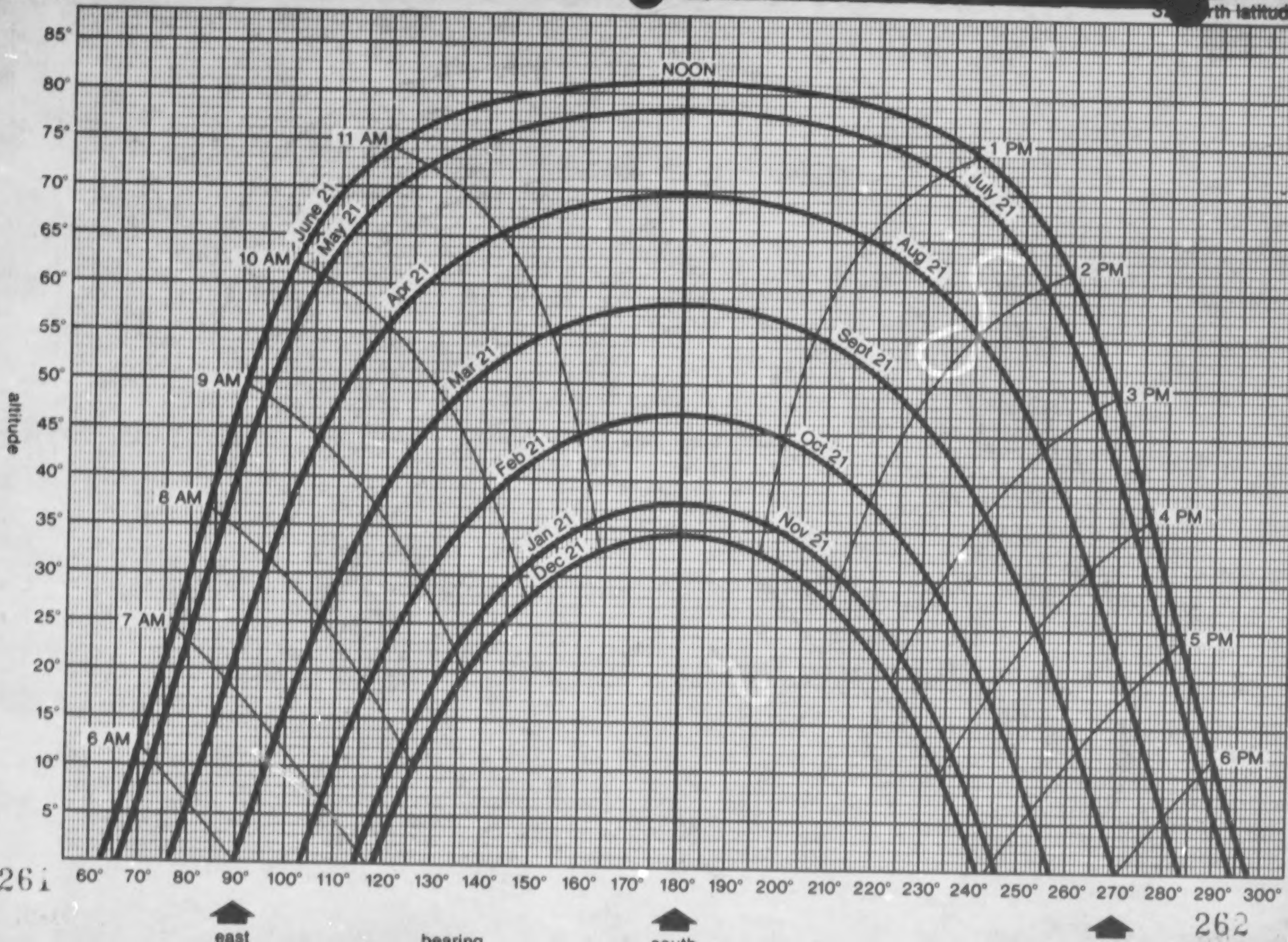
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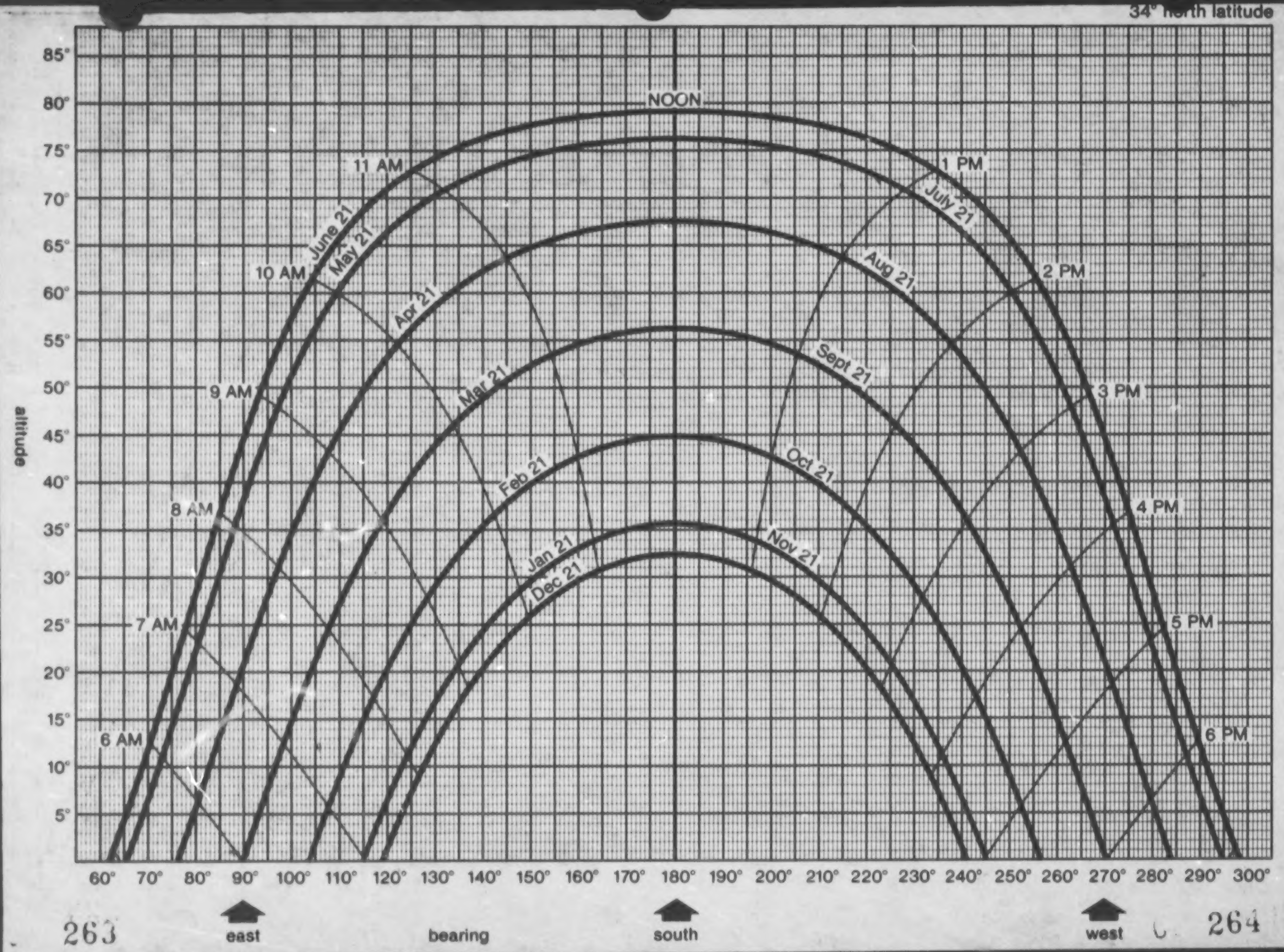

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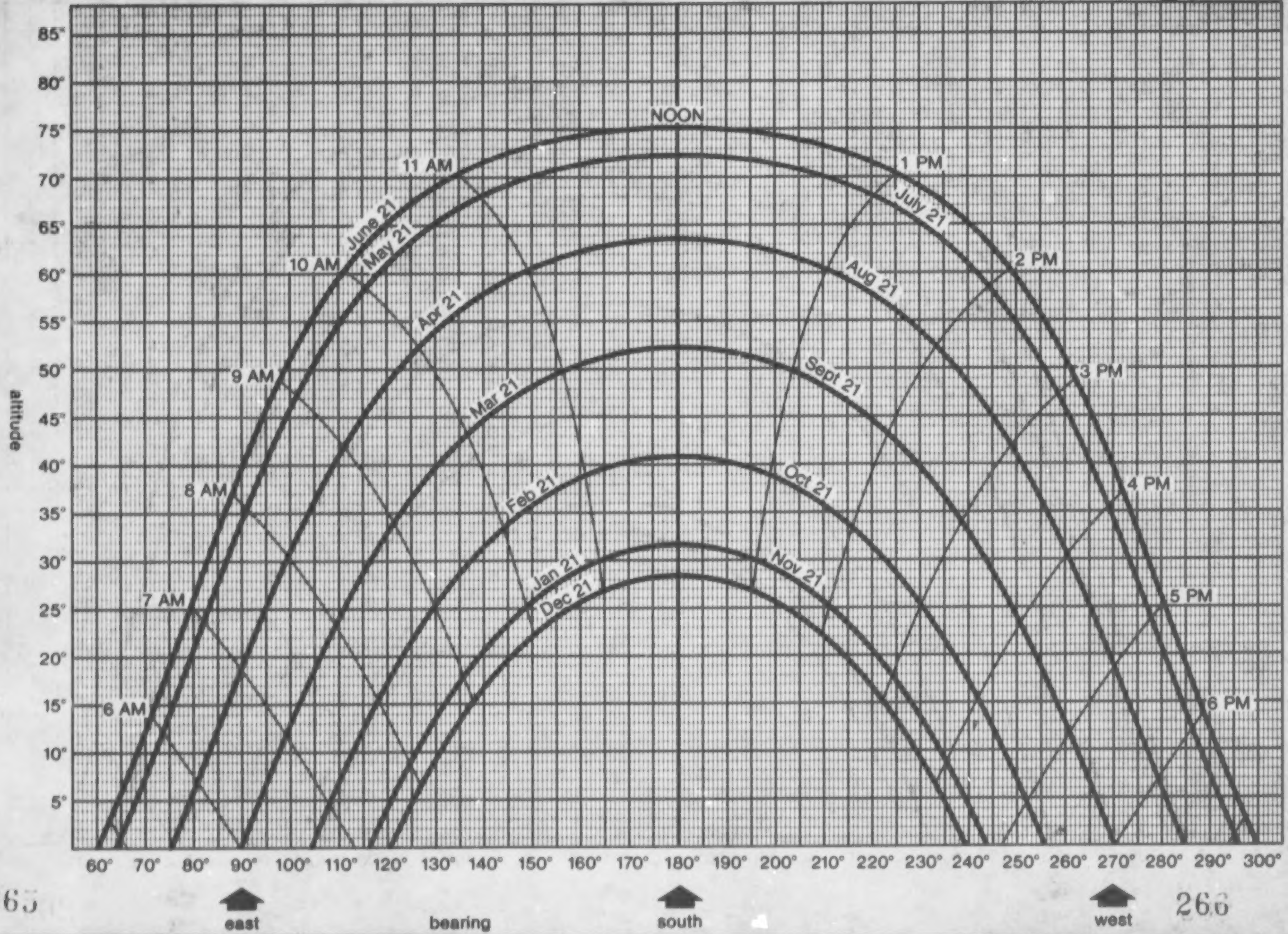

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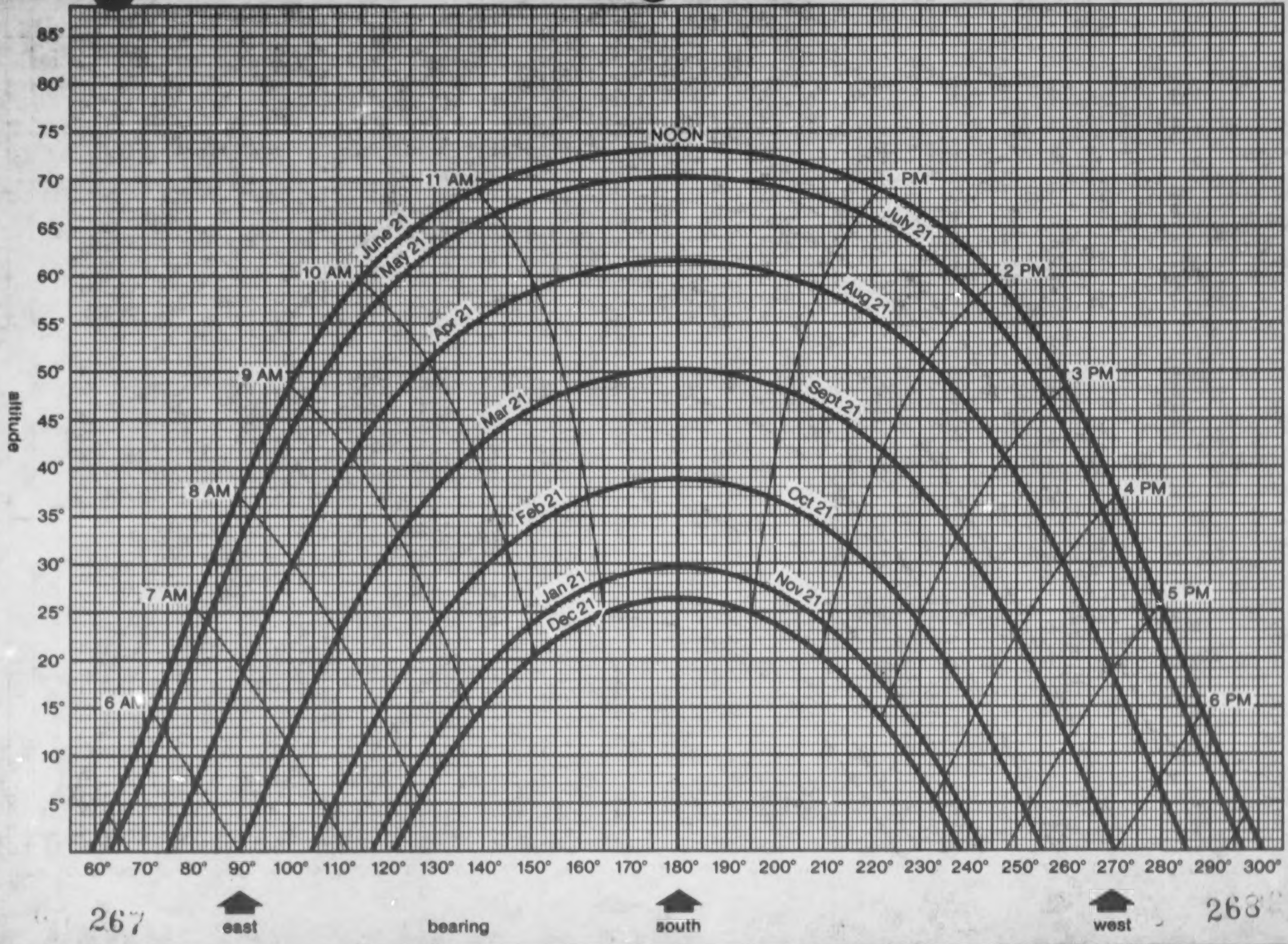

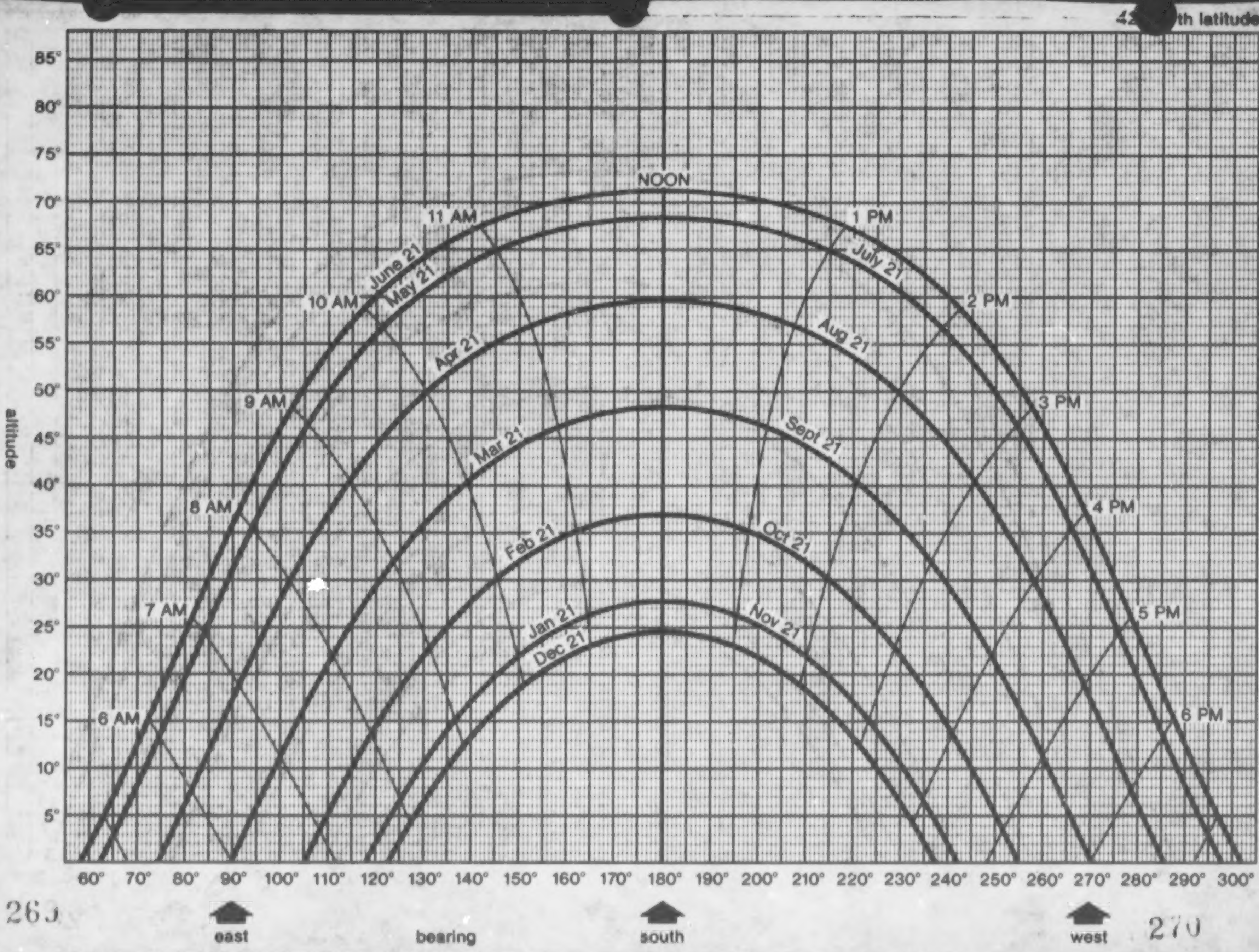
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Gas From Biomass

Note: This project takes weeks to achieve results; plan on going on to new topics before reaching closure on this one.

Objectives

This lesson contributes to students' understanding of the following ideas:

Methane can be made from waste materials through biological processes.

Format of the Lesson

(This is a teacher demonstration)

Discuss energy content of manure

Discuss decomposition

Discuss purpose of different parts of apparatus, and assemble

Charge with manure

(Then, at intervals of several days, have the class observe what has happened. Eventually ignite the gas, and disassemble).

Materials Needed

starter starter, like the starter in making sourdough bread, is any material that contains a large number of the particular microorganisms we need. The digester will work without starter, but adding the starter shaves about two weeks off the wait before results become evident. Make the starter by putting some manure and several handfuls of grass clippings in water in a loosely stoppered bottle. Let sit for 6-8 weeks in a place where the temperature is between 70 and 90 degrees Fahrenheit.

two-hole stopper to fit bottle

bottle one gallon, glass or plastic, but it should be clear so that students can observe what happens inside.

glass tubing this can be found in a high school chemistry lab; if you aren't familiar with heating tubing to bend it, ask a teacher or student to make you a manometer and burner tip. These pieces are indicated in the drawing below.

Y-connector can be made from glass tubing, but it is easier to purchase one made of plastic or metal.

ring stands with clamps. Optional, but convenient for holding the glass tubing.

rubber tubing a few feet.

pinchcock

manure

plant matter see below.

vinegar a few tablespoons.

storage container for the gas produced. A large plastic bag, if you can get a heavy one without holes. Another possibility is the plastic liner from the cartons in which milk is delivered to restaurants and school cafeterias.

A Review of Precautions

Methane is an energy-packed fuel and requires respectful handling. A mixture of one part methane to 12-13 parts air will ignite explosively, but built into this demonstration are safety precautions to prevent this. These include:

1. The manometer not only indicates the pressure, it also acts as a safety valve. This function is lost if the tube is permitted to become clogged.

2. The burner tip prevents flame from traveling back into the gas supply. For this reason, it should be long and come to a rather fine tip.

3. Squeezing out as much air as possible in setting up the apparatus is essential. Make tubing runs as short as possible, of diameters no larger than necessary.

Preliminary Discussion

(A down-home example of anaerobic methane production with which everyone is familiar is flatulence – e.g., ask the students, what happens after you eat beans? This approach is too ribald for most classes – perhaps most teachers – use your good judgment.)

We need oxygen to get energy from the food we eat. But some simple living things don't need oxygen to get energy from complex organic molecules.

Examining the Raw Materials

Take the organic matter which you will decompose. Let's suppose you are using dried steer manure from a nursery.

Identify the substance for the students. Ask where it came from. (ANS: Cow droppings, solid excretia of cows – whatever terms are meaningful to the class.) Ask, before the cow, where did it come from? (ANS: Plants the cow ate.)

The cow got energy from the plant matter by taking molecules from the food into its body. Ask, is there any energy left in the cow manure? This can be a topic of much discussion. Students with farm backgrounds may point out such clues as: manure generates heat when it is composted; some insects seem to live in cow droppings. An obvious clue is that energy can be released by burning dung as the pioneers did buffalo chips or as the people of India do today.

Are there living things in the manure? Many students will recognize that there are "germs" in unsterilized manure, i.e., microscopic forms of plant and animal life.

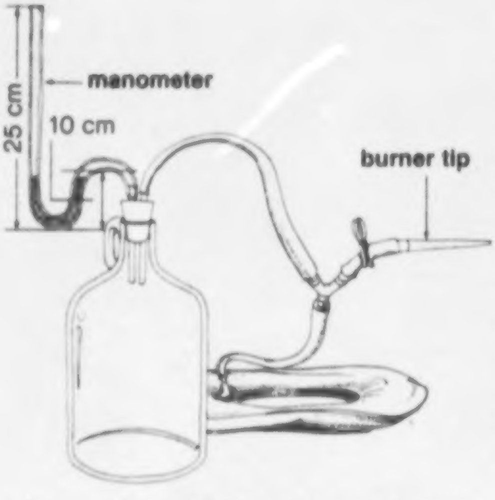
If we left a cow dropping alone in a field, what would happen to it? (ANS: Eventually it would disappear – decay.) What causes decay? (ANS: The microscopic plants and animals.) These organisms are called "decomposers."

It turns out that the bacteria of decay in air mostly produce the same respiration products we do: water and carbon dioxide. But if the decay takes place where there is no air a different kind of bacteria thrive. We call this, anaerobic (without air) decomposition.

The Apparatus

We can capture some of the energy in waste materials by using the microorganisms of anaerobic decay. We will use them to produce methane, the main component in natural gas.

Assemble the apparatus. It should look like this.



Into a clear gallon jar put some grass clippings and a few cupfuls of dried manure, covered with water. It is helpful but not essential to run this mixture through a blender to ensure a smooth slurry. Remind the students there is chemical energy in the manure and clippings — ask where it came from.

Adding a few tablespoons of vinegar will help to acidify the slurry and speed the creation of a favorable environment for the methane producing bacteria.

Add the starter, explaining how you made it and that this liquid is rich in the particular kind of microorganisms we want.

Cap the bottle with the 2-hole stopper and add water to the manometer, explaining that it serves as both a pressure gauge and safety valve. Connect the Y, burner tube and storage tank. Use a pinchcock to close off the burner tip.

Find a spot where the digester can be left undisturbed for a number of weeks. If temperature requirements can be met, outside is best — in any case, not near an open flame. The ideal temperature range is from 85 – 105°F; below 60°F, nothing happens.

From time to time, check the digester to see if gas is forming, and that the tubes have not been blocked by slurry.

Examining the Results

After a few weeks, the storage chamber will begin to fill with gas. Initially this will initially, this will be mostly carbon dioxide.

Place a pinchcock between the digester and storage bag; remove the one between the storage bag and burner tip. Using a match, try to light the escaping gas. While it is carbon dioxide, you will be unable to. The second bagful, however, should ignite. To make the flame visible to the students, hold a piece of black construction paper behind the burner tip. Be prepared to reignite the flame.

Projects for Independent Investigation

1. Especially at the beginning, the gas produced by the fermentation is rich in carbon dioxide, which doesn't burn. Of course, that dilutes the heating value of the gas. Can you devise a practical way of removing the carbon dioxide from the gas? (Think back to the experiments in Unit Two.)
2. What is the optimal acidity? . . . temperature? How could you find out?
3. What kinds of organic waste that might be decomposed for gas are available in your community?
4. Are the leftovers good fertilizer or not? Determine an answer experimentally.
5. Why is methane sometimes called "marsh gas?"

Unit Six
Energy in the United States

Off to the Wilderness

Suppose you were going to a wilderness where you could depend only on yourself. What would you take with you?

The people who left England to settle the new colony of Virginia in the early 1600's had just such a problem. To guide them, the leader of the colony, Captain John Smith (remember Pocahontas?) made the following list. Read it over, then answer the questions.

A particular of such necessaries as either private families, or single persons, shall have cause to provide to goe to Virginia, whereby greater numbers may in part conceive the better how to provide for themselves.

Apparell for one man, and so after the rate for more.

A Monmoth Cap.	1s.	10d.	
3 falling bands.	1s.	3d.	
3 shirts.	7s.	6d.	
1 Waste-coat.	2s.	2d.	
1 suit of Canvase.	7s.	6d.	
1 suit of Frize.	10s.		Frize = Frieze, a coarse woolen cloth
1 suit of Cloth.	15s.		
3 pair of Irish stockings	4s.		
4 paire of shooes.	8s.	8d.	
1 paire of garters.		10d.	
1 dozen of points.		3d.	Points = laces for fastening clothing, similar to shoelaces
1 paire of Canvas sheets.	8s.		
7 ells of Canvas to make a bed and boulster, to be filled in Virginia, serving for two men.	8s.		Ell = a unit of length, about a yard Boulster = a large pillow
5 ells of course Canvas to make a bed at Sea for two men.	5s.		
1 course rug at sea for two men.	6s.		
4£.			

Victuall for a whole yeare for a man, and so after the rate for more.

8 bushels of meale.	2£.		Meale = wheat flour
2 bushels of pease.	6s.		
2 bushels of Otemeale.	9s.		
1 gallon of Aquavitae.	2s.	6d.	Aquavitae = a strong alcoholic beverage
1 gallon of oyle.	3s.	6d.	
2 gallons of Vinegar.	2s.		
3£.	3s.		

From **The General History of Virginia** by Captain John Smith, 1624; The Fourth Book.

Armes for a man; but if halfe your men be armed it is well, so all have swords and peeces.

1 Armor compleat, light.		17s.	
1 long peece five foot and a halfe, neere Musket bore.	1£.	2s.	
1 Sword.		5s.	
1 Belt.		1s.	
1 Bandilier.		1s.	6d.
20 pound of powder.		18s.	
60 pound of shot or Lead, Pistoll and Goose shot.		5s.	
	3£.	9s.	6d.

Peece = a firearm

Bandileer = a broad leather belt worn over the left shoulder

Tooles for a family of six persons, and so after the rate for more.

5 broad howes at 2s. a peece.	10s.	
5 narrow howes at 16d. a peece.	6s.	8d.
2 broad axes at 3s. 8d. a peece.	7s.	4d.
5 feling axes at 18d. a peece.	7s.	6d.
2 steele handsawes at 16d. a peece.	2s.	8d.
2 two handsawes at 5s. a peece.	10s.	
1 whipsaw, set and filed; with box, file and wrest.	10s.	
2 hammers 12d. a peece.	2s.	
3 shovels at 18d. a peece.	4s.	6d.
2 spades at 18d. a peece.	3s.	
2 Augers at 6d. a peece.	1s.	
6 Chissels at 6d. a peece.	3s.	
2 Percers stocked 4d. a peece.		8d.
3 Gimlets at 2d. a peece.		6d.
2 Hatchets at 21d. a peece.	3s.	6d.
2 frowes[2] to cleave pale 18d. each.	3s.	
2 hand Bills 20ds. a peece.	3s.	4d.
1 Grindstone.	4s.	

Two handsawe = a saw for two hands, i.e. one person at each end.

Frowes = froes.

Nailes of all sorts to the value of	2£.		
2 Pickaxes.		3s.	2s.
	6£.	2s.	8d.

Household equipment for a family of six persons, and so for more or lesse after the rate.

1 Iron pot.		7s.	
1 Kettell.		6s.	
1 Large Frying-pan.		2s.	6d.
1 Gridiron.		1s.	6d.
2 Skellets.		5s.	
1 Spit.		2s.	
Platters, dishes, spoones of wood.		4s.	8d.
	1£.		

For Sugar, Spice, and Fruit, at Sea for six men.

12s. 6d.

So the full charge after this rate for each person, will amount to about the summe of

12£ 10s. 10d.

The passage of each man is

6£.

The fraught of these provisions for a man, will be about halfe a tun, which is

1£. 10s.

So the whole charge will amount to about 20£.

Now if the number be great; Nets, Hooks, and Lines, but Cheese, Bacon, Kine and Goats must be added. And this is the usuall proportion the Virginia Company doe bestow upon their Tenents they send.

Reading Carefully

1. Smith lists two kinds of chemical energy. What are they?

2. Many tools are listed. What provided the power for the tools?

3. Could you live for a year on the food Smith lists? (The question isn't whether you would want to.) What other food sources are implied by the list of tools?

4. Why is "sugar, spice, and fruit" needed at sea?

5. What raw materials are represented? What are the tools made of? How was energy important in obtaining these raw materials? In which forms was the energy obtained?

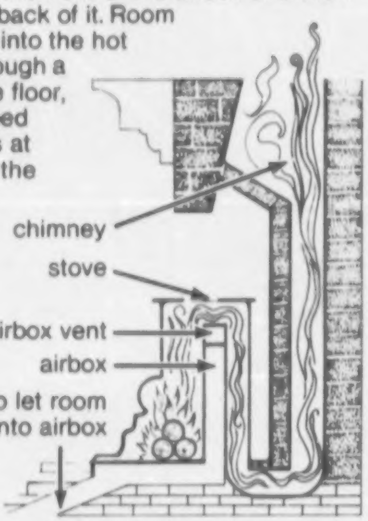
Benjamin Franklin's Stove

Benjamin Franklin was the most famous American of his day. Not only was he a great scientist, but also the most popular American writer, our ambassador to our most important foreign ally, a successful businessman, and one of the people who invented the system of government we still use 200 years later.

Franklin was also an inventor who used his understanding of science to solve people's problems. One of his inventions that is still used is the Franklin Stove. In a Franklin Stove, the hot air from a wood fire is drawn down around an iron chamber in the back of the stove. As this happens, much of the heat in the air is transferred to the iron and then to the air in the iron box, which is let out into the room.

The description below is taken from an advertising pamphlet Franklin wrote to sell his stoves.

The secret of Franklin's iron fireplace was a false back, which was the front side of the hollow airbox. Smoke from the fire flowed up the front of the airbox and then down the back of it. Room air flowed into the hot airbox through a hole in the floor, and escaped from vents at the top of the air box.



From: An Account of the Newly Invented Pennsylvanian Fire-Place

by Benjamin Franklin, Philadelphia, 1744

In these Northern Colonies the Inhabitants keep Fires to sit by, generally Seven Months in the Year; that is, from the Beginning of October to the End of April; and in some winters near Eight Months, by taking in part of September and May.

Wood, our common Fuel, which within these 100 Years might be had at every Man's Door, must now be fetch'd near 100 Miles to some Towns, and makes a very considerable Article in the Expense of Families.

As therefore so much of the Comfort and Conveniency of our Lives, for so great a Part of the Year, depends on the Article of FIRE; – since Fuel is become so expensive, and (as the Country is more cleared and settled) will of course grow scarcer and dearer; any new Proposal for Saving the Wood, and for lessening the Charge and augmenting the Benefit of Fire, by some particular Method of Making and Managing it, may at least be thought worth Consideration.

The New Fire-Places are a late Invention to that purpose (experienced now three Winters by a great Number of Families in Pennsylvania) of which this Paper is intended to give a particular Account.

The Advantages of this Fire-Place

Its Advantages above the common Fire-places are:

1. That your whole Room is equally warmed; so that People need not crowd round the Fire, but may sit near the Window and have the Benefit of the Light for Reading, Writing, Needlework, etc. They may sit with Comfort in any Part of the Room; which is a very considerable Advantage in a large Family, because all cannot conveniently come at One.

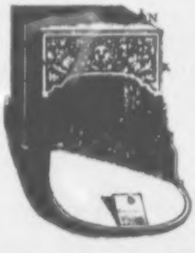
2. If you sit near the Fire, you have not that cold Draught of uncomfortable Air nipping your Back and Heels, as when before common Fires, by which many catch Cold, being scorched before and as it were froze behind.

3. If you sit against a Crevice, there is not that sharp Draught of cold Air playing on you, as in Rooms where there are Fires in the common way; by which many catch cold, whence proceed Coughs, Catarrhs, Toothaches, Fevers, Pleurisies and many other Diseases.

4. In Case of Sickness, they make most excellent Nursing-Rooms, as they constantly supply a Sufficiency of fresh Air, so warmed at the same time as to be no way inconvenient or dangerous.

5. In common Chimneys the strongest Heat from the Fire, which is upwards, goes directly up the Chimney, and is lost; and there is such a strong Draught into the Chimney, that not only the upright Heat, but also the back, sides and downward Heats, are carried up the Chimney by that Draught of Air; and the Warmth given before the Fire by the Rays that strike out towards the Room, is continually driven back, crowded into the Chimney, and carried up, by the same Draught of Air. – But here the upright Heat, strikes and heats the Top Plate, which warms the Air above it, and that comes into the Room. The Heat likewise which the Fire communicates to the Sides, Back Bottom and Air-Box, is all brought into the Room; for you will find a constant Current of Warm Air coming out of the Chimney-Corner into the Room. Hold a Candle just under the Mantle-Piece or Breast of your Chimney, and you will see the Flame bent outwards: By laying a Piece of smoking Paper on the Hearth, on either Side, you may see how the Current of Air moves, and where it sends, for it will turn and carry the Smoke with it.

6. Thus as very little of the heat is lost, when this Fire-Place is used, much less Wood* will serve you, which is a considerable Advantage where Wood is dear.



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* People who have used these Fire-places, differ much in their Accounts of the Wood saved by them. Some say five sixths, others three fourths, and others much less. This is owing to the great Difference there was in their former Fires; some (according to the different Circumstances of their Rooms and Chimneys) having been used to make very large, others middling, and others, of a more sparing Temper, very small Ones. While in these Fire-places (their Size and and Draught being nearly the same) the Consumption is more equal. I suppose, taking a Number of Families together, that two thirds, or half the Wood at least is saved. My common Room, I know, is made twice as warm as it used to be, with a quarter of the Wood I formerly consumed there.

7. When you burn Candles near this Fire-place, you will find that the Flame burns quite upright, and does not blare and run the Tallow down, by drawing towards the Chimney, as against common Fires.

8. This Fire-place cures most smoky Chimneys, and thereby preserves both the Eyes and Furniture.

9. It prevents the Fouling of Chimneys; much of the Lint and Dust that contributes to foul a Chimney being by the low Arch obliged to pass through the Flame, where it is consumed. Then, less Wood being burnt, there is less Smoke made. Again, the Shutter, or Trap-bellows, soon blowing the Wood into a Flame, the same Wood does not yield so much as if burnt is a common Chimney: For as soon as Flame begins, Smoke, in proportion, ceases.

10. And if a Chimney should be foul, 'tis much less likely to take Fire. If it should take Fire, 'tis easily stifled and extinguished.

11. A Fire may be very speedily made in this Fire-Place, by the help of the Shutter, or Trap-Bellows, as aforesaid.

12. A Fire may be soon extinguished, by closing it with the Shutter before, and turning the Register behind, which will stifle it, and the Brands will remain ready to rekindle.

13. The room being once warm, the Warmth may be retained in it all Night.

14. The lastly, the Fire is so secured at Night that not one Spark can fly out into the Room to do Damage.

With all these Conveniences, you do not lose the pleasant sight nor Use of the Fire, as in the Dutch Stoves, but may boil the Tea-Kettle, warm the Flat-Irons, heat Heaters, keep warm a dish of Victuals by setting it on the Top, &&.

Reading Carefully

1. How many months of the year did the people of Philadelphia (in the "Northern Colonies") keep fires?

2. Why does Franklin think wood is getting more expensive in big cities in 1774?

3. How much wood does Franklin claim the new fireplace will save?

4. Franklin says improving the fireplace will improve the lighting of the room. How?

5. From Franklin's list of improvements, what do you think the most disagreeable thing about heating a house with a fireplace would be?

An Ordinance: Baltimore, Maryland; June 17, 1816

Whereas, it is represented to the Mayor and City Council of Baltimore by Rembrandt Peale, on behalf of himself and others, who have associated and formed a company by the name and title of "The Gas Light Company of Baltimore," that they are willing to contract to light the streets, squares, lanes and alleys of this City, in a more effectual manner, and with more safety, convenience and beauty by means of Carburetted Hydrogen Gas than they heretofore have been lighted by means of oil, without causing any increased expense to the City for lighting the same extent of streets or space; and the said company have prayed that the Mayor be authorized to contract with them for that purpose; and also, that they may be authorized to lay pipes for the streets, squares, lanes and alleys of the City; and the City Council being desirous of giving every reasonable assistance to promote the laudable views of the said company, and of having the City lighted in the most effectual manner, which the means[1] usually appropriated to that object will accomplish; therefore,

1. Be it enacted and ordained by the Mayor and City Council of Baltimore, That it shall and may be lawful for "The Gas Light Company of Baltimore" aforesaid, and they are hereby authorized to proceed to lay or cause to be laid along and under the streets, squares, lanes and alleys of the City, paved or unpaved, such and so many pipes as may be necessary to convey the gas from their manufactory or manufactories, which they are hereby authorized to establish and carry on with the City, until such permission be revoked, to and along any street, square, lane or alley which they shall propose to light, and also to supply with light any house or other place belonging to any individual or company adjacent to any such street, square, lane or alley in or along which the said pipes shall be repair or remove. Provided always, That the said company shall not in any manner injure or displace any pipe or pipes laid or to be laid by the Baltimore Water Company for the purpose of conveying water into or through any part of the city or precincts; and provided also, That "The Gas Light Company of Baltimore" aforesaid shall, immediately after laying, repairing or removing any pipe or pipes as aforesaid, in any street or part of a street, square, lane or alley, and always within two days after being thereto required by the City Commissioners, cause to be filled up, repaired and repaved, at their own expense, every such street, or part of a street, square, lane or alley as the said company may find it necessary to dig, impair or unpave for the purpose of altering, laying or removing any pipe or pipes as aforesaid; and if the said company shall omit or neglect to fill up, repair, or repave any such street, square, lane or alley, or any part thereof, or shall omit or neglect to remove and take away any dirt or rubbish which may remain after the laying, altering or removing such pipe or pipes, or after filling up, repairing or repaving as aforesaid, for the space of forty-eight hours after the time, which shall be limited by the City Commissioners in their notice for that purpose, the said

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1. *means, that is, the amount of money.

company shall for every such omission or neglect forfeit and pay to the use of the City such sum not exceeding twenty dollars, as any Justice of the Peace for Baltimore County shall adjudge, on a warrant to be issued in the name of the Mayor and City Council of Baltimore against the president or other known officer of the said company, and also the sum of five dollars to be recovered as aforesaid, for every day they shall neglect or refuse so to do after the issuing of any warrant by a Justice of the Peace for the recovery of the said penalty of twenty dollars.

2. And be it enacted and ordained, That the said company shall be subject to all the penalties prescribed by the provisions of the ordiance entitled "An ordinance to encourage the introduction of water into the City of Baltimore," and of the several supplements thereto, so far as the same can within the intent and meaning of the ordinance be rendered applicable to the said company, and so far as they are not inconsistent with the provisions of this ordinance, and that the said company shall be particularly subjected to the provisions of the ordinance and supplements aforesaid respecting the repairing and repaving the streets, lanes and alleys through which the gas may be conveyed, removing the rubbish remaining from the laying or repairing the necessary pipes, and the repavement by the company of such streets, lanes or alleys as may be insufficiently repaved, or prove defective within six months from the time of their being repaved, and that the said penalties contained in the provisions of the said ordinance and supplements shall be recovered from the president or other known officer of the said company, before any Justice of the Peace in the mode hereinbefore prescribed and directed.

3. And be it enacted and ordained, That if any person shall impair, obstruct, displace or injure any pipe or any part of the machinery which shall be used or employed by the said company in manufacturing, conducting or conveying the said gas, or in any way impede the circulation, or cause a waste of the said gas, he or she, shall for every such offense, forfeit and pay such sum, not exceeding twenty dollars, as any Justice of the Peace shall adjudge, one-half to the use of the informer and the other half to the use of the city; and such person shall also be liable to pay damages for the injury which the said company may sustain.

4. And be it enacted and ordained, That the Mayor be, and he is hereby, authorized to contract with the said Rembrandt Peale and the other members of "The Gas Light Company of Baltimore," or with the agent or officer of the said company duly authorized for that purpose, to light the whole of the streets, squares, lanes and alleys of this city, or from time to time, for the lighting of any one street, or part of a street, square, lane or alley, as he may deem advisable, on such terms and conditions as to the Mayor shall appear reasonable: Provided, that no such contract shall be made for a longer period than one year, and also that the actual cost or expense of lighting the city in virtue or any such contract, shall not exceed the expense heretofore incurred for the same purpose, and the same proportion for lighting any street or streets, or any part of a street, unless the same shall be authorized by a future ordinance, and the Mayor is hereby authorized to pledge the faith of the city, that any contract or contracts made by him with the said company, under the restriction aforesaid, shall be continued, extended or renewed from year to year as long as the said company shall continue to light the city with as much economy, safety and as effectually as the same can or could be lighted by means of oil, or by any other company which may be established, or by any other means, and no longer; provided always, that the Mayor and the City Council of Baltimore reserve to themselves the right of annulling any such contract, and also of annulling and withdrawing any or all of the privileges granted by this ordinance if it shall at any time hereafter appear to the said Mayor and City Council, that the manufacture of gas or the use of it as a means of lighting the city, injures the health or endangers the property of the citizens in a greater degree than the use of oil for the same purpose.

5. And be it enacted and ordained, That "The Gas Light Company of Baltimore" aforesaid,may and they are hereby authorized, with the approbation of the Mayor and the consent of the owners or occupiers of houses fronting on or adjacent to any street, square, lane or alley, to attach the lamps, pipes or other apparatus to be used or necessary for lighting any such street, square, lane or alley, to any part of any such house or houses on such terms and conditions as may be agreed upon by and between the said company and the owner of occupier of such house or houses.

A Public Utility

1. Why did the city pass this ordinance?

2. What light source has the city been using up till now?

3. What special privileges does the ordinance give the company?

4. Which paragraph forbids people to interfere with the company's work?

5. Was there another public utility in Baltimore before Peale's gas company? What was it?

6. The ordinance forbids the gas company to interfere with certain other public services. What are they and how might the different services conflict? Do we still have this problem?

7. Paragraph 4 shows that the people who wrote the ordinance knew there was a risk in trying this new technology. What does it seem they thought the risks were? How were they going to decide if the benefits justified the risks?

8. Could Peale have established a service like this if the city had not passed an ordinance like this? If not, why not?

Transportation in America in the 1830s

Captain Marryat traveled around the United States by every means of transportation that was available in the 1830s. In one part of his book, he tells what he thinks about transportation in America.

But, before I enter into any remarks upon the various modes of travelling in America, it may be as well to say a few words upon the horses, which are remarkably good in the United States; they appear to be more hardy, and have much better hoofs, than ours in England; throwing a shoe therefore is not of the same consequence as it is with us, for a horse will go twenty miles afterwards with little injury. In Virginia and Kentucky the horses are almost all thoroughbred, and from the best English stock. The distances run in racing are much longer than ours, and speed without bottom is useless.

The Americans are very fond of fast trotting horses; I do not refer to rackers, as they term horses that trot before and gallop behind, but fair trotters, and they certainly have a description of horse that we could not easily match in England. At New York, the Third Avenue, as they term it, is the general rendezvous. I once went out there mounted upon Paul Pry, who was once considered the fastest horse in America: at his full speed he performed a mile in two minutes and thirty seconds, equal to twenty-four miles per hour. He took me at this devil of a pace as far as Hell Gate; not wishing "to intrude," I pulled up there, and went home again. A pair of horses in harness were pointed out to me who could perform the mile in two minutes fifty seconds. They use here light four-wheeled vehicles which they call wagons, with a seat in the front for two persons and room for your luggage behind; and in these wagons, with a pair of horses, they think nothing of trotting them seventy or eighty miles in a day, at a speed of twelve miles an hour; I have seen the horses come in, and they did not appear to suffer from the fatigue. You seldom see a horse bent forward, but they are all daisy cutters.

The gentlemen of New York give very high prices for fast horses; $1,000 is not by any means an uncommon price. In a country where time is everything, they put a proportionate value upon speed. Paul Pry is a tall grey horse (now thirteen years old); to look at, he would not fetch £10 – the English omnibusses would refuse him.

Talking about omnibusses, those of New York, and the other cities in America, are as good and as well regulated as those of Paris; the larger ones have four horses. Not only their omnibusses, but their hackney coaches are very superior to those in London; the latter are as clean as private carriages; and with the former there is no swearing, no dislocating the arms of poor females, hauling them from one omnibus to the other – but civility without servility.

The American stagecoaches are such as experience has found out to be most suitable to the American roads, and you have not ridden in them five miles before you long for the delightful springing of four horses upon the level roads of England. They are something between an English stage and a French diligence, built with all the panels open, on account of the excessive heat of the summer months. In wet weather these panels are covered with leather aprons, which are fixed on with buttons, a very insufficient protection in the winter, as the wind blows through the intermediate spaces, whistling into your ears, and rendering it more piercing than if all was open. Moreover, they are no protection against the rain or snow, both of which find their way in to you. The coach has three seats, to receive nine passengers, those on the middle seat leaning back upon a strong and broad leather brace, which runs across. This is very disagreeable, as the centre passengers, when the panels are closed, deprive the others of the light and air from the windows. But the most disagreeable feeling arises from the body of the coach not being upon springs, but hung upon leather braces running under it and supporting it on each side; and when the roads are bad or you ascend or rapidly descend the pitches (as they term short hills), the motion is very similar to that of being tossed in a blanket, often throwing you up to the top of the coach, so as to flatten your hat – if not your head.

The drivers are very skillful, although they are generally young men – indeed often mere boys – for they soon better themselves as they advance in life. Very often they drive six in hand; and if you are upset, it is generally more the fault of the road than of the driver. I was upset twice in one-half hour when I was traveling in the winter time; but the snow was very deep at the time, and no one thinks anything of an upset in America.

◆

In making my observations upon the railroad and steamboat travelling in the United States, I shall point out some facts with which the reader must be made acquainted. The Americans are a restless, locomotive people: whether for business or pleasure, they are ever on the move in their own country, and they move in masses. There is but one conveyance, it may be said, for every class of people – the coach, railroad, or steamboat, as well as most of the hotels, being open to all; the consequence is that the society is very much mixed – the millionaire, the well-educated woman of the highest rank, the Senator, the member of Congress, the farmer, the emigrant, the swindler, and the pickpocket are all liable to meet together in the same vehicle of conveyance. Some conventional rules were therefore necessary, and those rules have been made by public opinion – a power to which all must submit in America. The one most important, and without which it would be impossible to travel in such a gregarious way, is a universal deference and civility shown to the women, who may in consequence travel without protection all over the United States without the least chance of annoyance or insult. This deference paid to the sex is highly credit-able to the Americans: it exists from one end of the Union to the other: indeed, in the southern and more lawless states, it is even more chivalric than in the more settled. Let a female be ever so indifferently clad, whatever her appearance may be, still it is sufficient that she is a female; she has the first accommodation, and until she has it, no man will think of himself. But this deference is not only shewn in travelling, but in every instance. An English lady told me that, wishing to be present at the inauguration of Mr. Van Buren, by some mistake, she and her daughters alighted from the carriage at the wrong entrance, and in attempting to force their way through a dense crowd were nearly crushed to death. This was perceived, and the word was given – "Make room for the ladies." The whole crowd, as if by one simultaneous effort, compressed itself to the right and left, locking themselves together to meet the enormous pressure, and made a wide lane, through which they passed with ease and comfort. "It reminded me of the Israelites passing through the Red Sea with the wall of waters on each side of them," observed the lady. "In any other country we must have been crushed to death."

When I was on board one of the steamboats, an American asked one of the ladies to what she would like to be helped. She replied, to some turkey, which was within reach, and off of which a passenger had just cut the wing and transferred it to his own plate. The American who had received the lady's wishes immediately pounced with his fork upon the wing of the turkey and carried it off to the young lady's plate; the only explanation given, "For a lady, sir!" was immediately admitted as sufficient.

◆

Of all travelling, I think that by railroad the most fatiguing, especially in America. After a certain time the constant coughing of the locomotive, the dazzling of the vision from the rapidity with which objects are passed, the sparks and ashes which fly in your face and on your clothes become very annoying; your only consolation is the speed with which you are passing over the ground.

The railroads in America are not so well made as in England, and are therefore more dangerous; but it must be remembered that at present nothing is made in America but to last a certain time; they go to the exact expense considered necessary and no further; they know that in twenty years they will be better able to spend twenty dollars than one now. The great object is to obtain quick returns for the outlay, and, except in a few instances, durability or permanency is not thought of. One great cause of disasters is that the railroads are not fenced on the sides, so as to keep the cattle off them, and it appears as if the cattle who range the wood are very partial to take their naps on the roads, probably from their being drier than the other portions of the soil. It is impossible to say how many cows have been cut into atoms by the trains in America, but the frequent accidents arising from these causes have occasioned the Americans to invent a sort of shovel, attached to the front of the locomotive which takes up a cow, tossing her off right or left. At every fifteen miles of the railroads there are refreshment rooms; the cars stop, all the doors are thrown open, and out rush the passengers like boys out of school, and crowd round the tables to solace themselves with pies, patties, cakes, hard-boiled eggs, ham, custards, and a variety of railroad luxuries, too numerous to mention. The bell rings for departure, and in they all hurry with their hands and mouths full, and off they go again, until the next stopping place induces them to relieve the monotony of the journey by masticating without being hungry.

The Utica railroad is the best in the United States. The general average of speed is from fourteen to sixteen miles an hour; but on the Utica they go much faster. A gentleman narrated to me a singular specimen of the ruling passion which he witnessed on an occasion when the rail-cars were thrown off the road, and nearly one hundred people killed, or injured in a greater or less degree.

On the side of the road lay a man with his leg so severely fractured that the bone had been forced through the skin and projected outside his trousers. Over him hung his wife, with the utmost solicitude, the blood running down from a severe cut received on her head, and kneeling by his side was his sister, who was also much injured. The poor women were lamenting over him, and thinking nothing of their own hurts; and he, it appears, was also thinking nothing about his injury, but only lamenting the delay which would be occasioned by it.

"Oh! my dear, dear Isaac, what can be done with your leg?" exclaimed the wife in the deepest distress.

"What will become of my leg!" cried the man. "What's to become of my business, I should like to know?"

"Oh! dear brother," said the other female, "don't think about your business now; think of getting cured."

"Think of getting cured – I must think how the bills are to be met, and I not there to take them up. They will be presented as sure as I lie here."

"Oh! never mind the bills, dear husband – think of your precious leg."

"Not mind the bills! But I must mind the bills – my credit will be ruined."

"Not when they know what has happened, brother. Oh! dear, dear – that leg, that leg."

"D---n the leg; what's to become of my business?" groaned the man, falling on his back from excess of pain.

Now this was a specimen of true commercial spirit. If this man had not been nailed to the desk, he might have been a hero...

The most general, the most rapid, the most agreeable, and, at the same time, the most dangerous of American travelling is by steamboats...

The American steamboats are very different from ours in appearance, in consequence of the engines being invariably on deck. The decks also are carried out many feet wider on each side than the hull of the vessel, to give

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space; these additions to the deck are called guards. The engine being on the first deck, there is a second deck for the passengers, state-rooms, and saloons; and above this deck there is another, covered with a white awning. They have something the appearance of two-deckers, and when filled with company, the variety of colors worn by the ladies have a very novel and pleasing effect. The boats which run from New York to Boston, and up the Hudson River to Albany, are very splendid vessels; they have low-pressure engines, are well commanded, and I never heard of any accident of any importance taking place; their engines are also very superior – one on board of the *Narragansett,* with a horizontal stroke, was one of the finest I ever saw. On the Mississippi, Ohio, and their tributary rivers, the high-pressure engine is invariably used; they have tried the low-pressure, but have found that it will not answer, in consequence of the great quantity of mud contained in solution on the waters of the Mississippi, which destroys all the valves and leathers; and this is the principal cause of the many accidents which take place. At the same time it must be remembered that there is a recklessness – an indifference to life – shown throughout all America, which is rather a singular feature, inasmuch as it extends east as well as west. It can only be accounted for by the instiate pursuit of gain among a people who consider that time is money, and who are blinded by their eagerness in the race for it, added to that venturous spirit so naturally imbibed in a new country at the commencement of its occupation. It is communicated to the other sex, who appear equally indifferent. The *Moselle* had not been blown up two hours before the other steamboats were crowded with women, who followed their relations on business or pleasure, up and down the river. "Go ahead" is the motto of the country; both sexes join in the cry; and they do go ahead – that's a fact!*...

At present, it certainly is more dangerous to travel one week in America than to cross the Atlantic a dozen times. The number of lives lost in one year by accidents in steamboats, railroads, and coaches was estimated, in a periodical which I read in America, at one thousand seven hundred and fifty!

An excerpt from *A Diary in America with Remarks on Its Institutions*, by Captain Frederick Marryat (London, 1839).

*When the water in the rivers is low, the large steam vessels very often run aground, and are obliged to discharge their cargoes and passengers. At these times, the smaller steamboats ply up and down the rivers to take advantage of these misfortunes by picking up passengers and making most exhorbitant charges for taking them or the goods out, because you must pay them or remain where you are. This species of cruising they themselves designate as "going a-pirating." I will say this for the Americans, that, if a person, who considers that he is not doing wrong, does not do wrong, they are a very honest people.

Salt

Captain Marryat went on a trip on the Erie Canal, through New York State. On the way he passed a local industry.

After you pass Syracuse, the country wears a more populous and inviting appearance. Salina is a village built upon a salt spring, which has the greatest flow of water yet known, and this salt spring is the cause of the improved appearance of the country; the banks of the canal for three miles are lined with buildings for the boiling down of the salt water, which is supplied by a double row of wooden pipes. Boats are constantly employed up and down the canal, transporting wood for the supply of the furnaces. It is calculated that two hundred thousand cord of wood are required every year for the present produce; and as they estimate upon an average about sixty cord of wood per acre in these parts, those salt works are the means of yearly clearing away upwards of three thousand acres of land. Two million of bushels of salt are boiled down every year; it is packed in barrels, and transported by the canals and lakes to Canada, Michigan, Chicago, and the far west. When we reflect upon the number of people employed in the manufactories, and in cutting wood, and making barrels, and engaged on the lakes and canals in transporting the produce so many thouand miles, we must admire the spring to industry which has been created by this little, but bounteous, spring presented by nature.

Reading Carefully

1. How did the people get the salt from salt water?
2. Why does Marryat say this industry caused "improved appearance of the countryside?" What does he mean by "clearing away?"
3. How was the salt water carried from the spring to the place where it was boiled down?
4. How did the canal help make this industry possible?

Thinking It Over

1. How many cords of wood were used to get one bushel of salt?
2. One cord of air-dry hardwood weighs about 3,500 pounds and yields 20 million Btu when burnt. A gallon of fuel oil yields around 150,000 Btu. How many gallons of fuel oil would be equivalent to the wood burned in this industry?
3. What was salt used for in 1837? How do we do those things today? What changes in the use of energy has that made?

An excerpt from **A Diary in America with Remarks on Its Institutions**, by Captain Frederick Marryat (London, 1839).

No Midwestern Industry?

In the following paragraph, Captain Marryat makes a prediction. As you read, think about whether the prediction has come true in the 142 years since he wrote.

As soon as the eastern states are no longer permitted to remain the factors of the western, they must be content to become manufacturing states, and probably will compete with England. The western states, providentially, I may say, are not likely to be manufacturers to any great extent, for they have not water power; the valley of the Mississippi is an alluvial flat, and although the Missouri and Mississippi are swift streams, in general the rivers are sluggish, and at all events, they have not the precipitate falls of water necessary for machinery, and which abound in the northeastern states; indeed, if the western states were to attempt to manufacture, as well as to produce, they would spoil the market for their own produce. Whatever may be the result, whether the eastern states submit quietly to be shorn of their greatness (a change which must take place) or to contest the point until it ends in a separation, this is certain, that the focus of American wealth and power will eventually be firmly established in the free states on the other side of the Allegheny mountains.

Reading Carefully

1. Why does Marryat think the states west of the Alleghenies will never be great manufacturing states?

Thinking It Over

1. Was Marryat right in thinking there were no great waterfalls in the Mid-West?
2. Has any hydroelectric power been developed in the Mid-West? How was this possible if there weren't many natural waterfalls?
3. Did the Mid-West become a great manufacturing area?
4. Marryat made a false assumption. What was it?

An excerpt from **A Diary in America with Remarks on Its Institutions**, by Captain Frederick Marryat London, 1839).

The End of Steamboating Days

From 1856 to 1861, Samuel Clemens was a pilot of steamboats on the Mississippi River. Later, as Mark Twain, he became one of the greatest American writers. In 1882, 21 years after leaving the river, Mark Twain returned to visit the places he had worked. This is what he found at Saint Louis.

The further we drove in our inspection-tour, the more sensibly I realized how the city had grown since I had seen it last; changes in detail became steadily more apparent and frequent than at first, too: changes uniformly evidencing progress, energy, prosperity.

But the change of changes was on the 'levee*.' This time, a departure from the rule. Half a dozen sound-asleep steamboats where I used to see a solid mile of wide-awake ones! This was melancholy, this was woful. The absence of the pervading and jocund* steamboatman from the billiard-saloon was explained. He was absent because he is no more. His occupation is gone, his power has passed away, he is absorbed into the common herd, he grinds at the mill, a shorn Samson* and inconspicuous. Half a dozen lifeless steamboats, a mile of empty wharves, a negro fatigued with whiskey stretched asleep, in a wide and soundless vacancy, where the serried* hosts of commerce used to contend![1] Here was desolation, indeed.

'The old, old sea, as one in tears,
  Comes murmuring, with foamy lips,
And knocking at the vacant piers,
  Calls for his long-lost multitude of
    ships.'

The towboat and the railroad had done their work, and done it well and completely. The mighty bridge, stretching along over our heads, had done its share in the slaughter and spoliation. Remains of former steamboatmen told me, with wan satisfaction, that the bridge doesn't pay. Still, it can be no sufficient compensation to a corpse, to know that the dynamite that laid him out was not of as good quality as it had been supposed to be.

The pavements along the river front were bad: the sidewalks were rather out of repair: there was a rich abundance of mud. All this was familiar and satisfying; but the ancient armies of drays†, and struggling throngs of men, and mountains of freight, were gone; and Sabbath reigned in their stead. The immemorial mile of cheap foul doggeries† remained, but business was dull with them; the multitudes of poison-swilling Irishmen had departed, and in their places were a few scattering handfuls of ragged negroes, some drinking, some drunk, some nodding, others asleep. St. Louis is a great and prosperous and advancing city; but the river-edge of it seems dead past resurrection.

Mississippi steamboating was born about 1812; at the end of thirty years, it had grown to mighty proportions; and in less than thirty more, it was dead! A strangely short life for so majestic a creature. Of course it is not absolutely dead, neither is a crippled octogenarian who could once jump twenty-two feet on level ground; but as contrasted with what it was in its prime vigour, Mississippi steamboating may be called dead.

*the raised banks of the river

†wagons used to haul goods

*mirthful

†cheap saloons

*The Bible story is in Judges 16:4-21.

*crowded, pressed together

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[1] Capt. Marryat, writing forty-five years ago, says:
"St. Louis has 20,000 inhabitants. The river abreast of the town is crowded with streamboats, lying in two or three tiers."

It killed the old-fashioned keel-boating, by reducing the freight-trip to New Orleans to less than a week. The railroads have killed the steamboat passenger traffic by doing in two or three days what the steamboats consumed a week in doing; and the towing-fleets have killed the through-freight traffic by dragging six or seven steamerloads of stuff down the river at a time, at an expense so trivial that steamboat competition was out of the question.

Freight and passenger way-traffic remains to the steamers. This is in the hands – along the two thousand miles of river between St. Paul and New Orleans – of two or three close corporations well fortified with capital; and by able and thoroughly businesslike management and system, these make a sufficiency of money out of what is left of the once prodigious steamboating industry. I suppose that St. Louis and New Orleans have not suffered materially by the change, but alas for the wood-yard man!

He used to fringe the river all the way; his close-ranked merchandise stretched from the one city to the other, along the banks, and he sold uncountable cords of it every year for cash on the nail; but all the scattering boats that are left burn coal now, and the seldomest spectacle on the Mississippi today is a wood-pile. Where now is the once wood-yard man?

Reading Carefully

1. What new forms of transportation had taken the place of the steamboat?
2. What was the name of the job of the person who sold energy to the steamboats?
3. Why did people prefer the steamboat to the keel-boat?
4. Why did people prefer the railroad to the steamboat?
5. For carrying freight, why did people prefer the towing-fleet to the steamboats?
6. What fuel did the steamboats burn when Mark Twain was a pilot? What fuel does he say the few remaining boats are burning?

Thinking It Over

1. Can you think of any occupations today that might be gone or sharply reduced by an energy transition, the way the woodyard man's was? What would they be, and why do you think they might change.
2. Mark Twain doesn't specifically mention any new jobs, but the changes he describes imply that many different new jobs were created. How many can you list?
3. What do you think Twain's feelings were when he saw the Saint Louis waterfront? Why did he feel that way? Why does a person find some changes sad?

Finding out More Information

1. What was "old-fashioned keel-boating"? What was its source of energy?
2. What products did boats carry on the Mississippi in 1810... in 1858?... in 1881?
3. A hundred years have passed since Twain's visit to Saint Louis. Is there still river traffic on the Mississippi? What is carried? What source of energy is used?

Pioneers on the Great Plains 1

Objectives

The purpose of this lesson is to focus the students' attention on the time and place we will be studying, and introduce the primary source materials to be used.

Teacher Background

In the closing decades of the 1800s the daily life of the average American began to be affected greatly by the use of powered machinery and fossil fuels. The transition from millenia of muscle power and wood had begun.

In this set of lessons, we will try to help students feel what it was like to live in those times, and to compare how people did things in those days with how we do them now.

In the first section, we use as a backbone the series of autobiographical **Little House on the Prairie** books written by Laura-Ingalls Wilder. These books are well within the reading ability of seventh-graders, and even many fourth-graders; yet they are masterpieces that hold the attention of adults. Because the activities suggest additional readings from the books, we recommend that you make multiple copies available for students in the classroom. The whole set is available boxed in paperbound for $19.95.

The individual volumes with greatest usefulness for this project are **Little House on the Prairie, Little Town on the Prairie,** and **Farmer Boy;** they typically cost about $2.00 each. The paperbound (Torch edition) and hardbound editions have the same page numbers.

Materials Needed

wall map of United States.

reading **By the Hearth.**

Wilder Books

reading **A Sudden Storm.**

Identify the Time and Place

Use the wall map to show the United States. Discuss how people moved from the Atlantic seaboard westward.

Ask, what did these people do for a living? What were they looking for?

Discuss the different kinds of land the pioneers found as they moved westward — the Appalachian barrier, then moving on to the Great Plains.

Ask, when was the first transcontinental railroad completed? Locate its route on the map. This connected the eastern states with California. But the Great Plains were not yet settled. They did not appear as fertile to farmers as the woodlands they were used to. These areas were not really settled until after the Civil War.

Introducing Laura Ingalls Wilder

Tell the class about the little girl who went with her family from one state to another. Trace their route on the wall map, using the map below.

Tell the class that this girl became an author and wrote a series of books which a generation of readers has recognized as classics. The characters of these books were used to make a television series, Little House on the Prairie — but you may want to point out that what happens in the television series is not exactly the same as what happens in the books.

You may also wish to explore with the students the problem of the veracity of eyewitness reports. We know that in some respects Laura's account is inaccurate. We know this because we can compare her version with the versions of other eyewitnesses who made records. Similarly in a trial, different witnesses to a car accident may remember it differently, but by comparing these versions the jury reaches a decision about what happened. The historian goes through a similar process.

We are fortunate that Laura has lovingly described the farmers' and pioneers' chores in such detail, for these descriptions give us a good picture of how energy was used in those days.

The First Reading

Pass out the reading, **By the Hearth.**

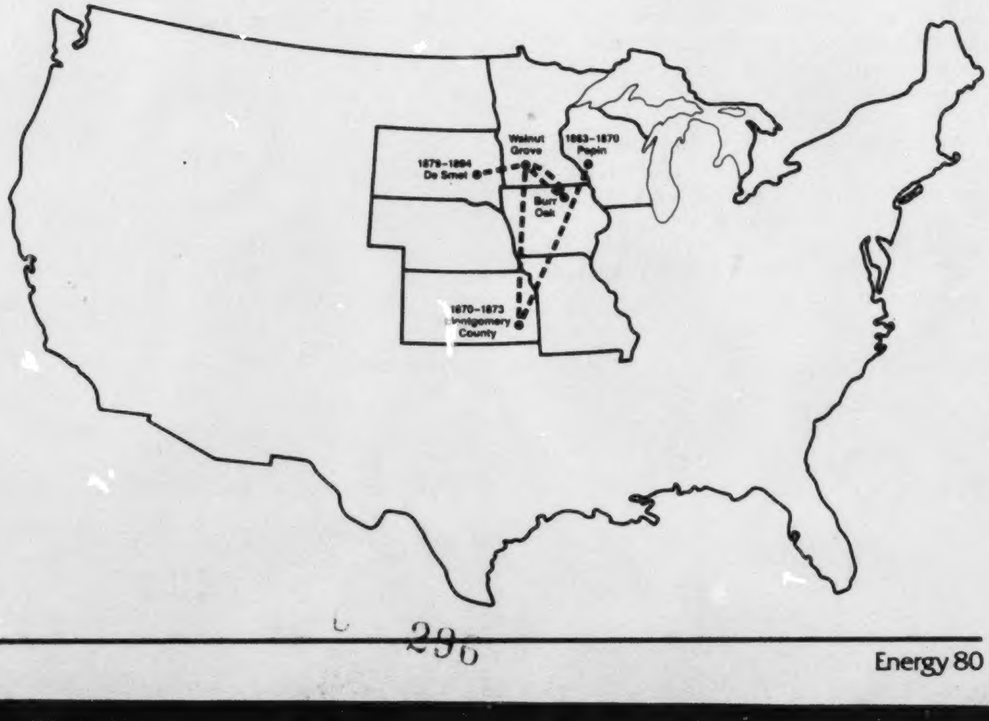
Allow time for students to read the paragraphs silently to themselves. Let students who finish early prepare written answers to the "Thinking It Over" questions.

Discussion

Call on students for answers to the recall questions in "Reading Carefully." Then discuss the second set of questions. Try to focus the students' attention on people's need for certain things to live.

Homework Assignment

Assign the reading, **A Sudden Storm** and the associated questions for homework.



By the Hearth

About a hundred years ago, pioneering farmers were moving into the prairies of the middle United States. One of these families was the Ingalls, who moved from Wisconsin to Minnesota, to Iowa, to Missouri, to Kansas, back to Minnesota, back to Iowa, and finally to South Dakota. The second oldest of the Ingalls' children was Laura. When Laura grew up, she wrote eight books describing her family's adventures.

Laura's true stories have become some of the best-loved books ever written by an American. You may have seen the television series, **Little House on the Prairie**, based on the characters in the books. But the books themselves are even more interesting, and are one of the best pictures we have of life in pioneer American in the 1880's.

Then the fire was shining on the hearth, the cold and the dark and the wild beasts were all shut out, and Jack the brindle bulldog and Black Susan the cat lay blinking at the flames in the fireplace.

Ma sat in her rocking chair, sewing by the light of the lamp on the table. The lamp was bright and shiny. There was salt in the bottom of its glass bowl with the kerosene, to keep the kerosene from exploding, and there were bits of red flannel among the salt to make it pretty. It was pretty.

Laura loved to look at the lamp, with its glass chimney so clean and sparkling, its yellow flame burning so steadily, and its bowl of clear kerosene colored red by the bits of flannel. She loved to look at the fire in the fireplace, flickering and changing all the time, burning yellow and red and sometimes green above the logs, and hovering blue over the golden and ruby coals.

And then, Pa told stories.

Reading Carefully

1. What animals were allowed inside the house?
2. What was Ma doing?
3. How was the house heated?
4. How was the house lit?

Thinking It Over

1. Would you like to live the way Laura did?
2. What do people need to live? to feel safe and comfortable?
3. Two energy sources were being used in the Ingalls' home. What were they? How do you think the Ingalls got them?
4. What good did the family get out of consuming this energy?

Finding out More Information

1. Where does the word "kerosene" come from? What does it mean today? Did it always mean that?

Text excerpt from **LITTLE HOUSE IN THE BIG WOODS** by Laura Ingalls Wilder. Copyright, 1932, as to text, by Laura Ingalls Wilder. Renewed 1959 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

A Sudden Storm

Mary was angry and so was Laura. They would have gone on quarreling, but suddenly there was no sunshine. They ran to look through the bedroom window.

A dark cloud with a fleecy white underside was rolling fast from the north-west.

Mary and Laura looked out the front window. Surely it was time for Pa and Ma to come, but they were nowhere in sight.

"Maybe it's a blizzard," said Mary.

"Like Pa told us about," said Laura.

They looked at each other through the grey air. They were thinking of those children who froze stark stiff.

"The woodbox is empty," said Laura.

Mary grabbed her. "You can't." said Mary. "Ma told us to stay in the house if it stormed," Laura jerked away and Mary said, "Besides, Jack won't let you."

"We've got to bring in wood before the storm gets here," Laura told her. "Hurry!"

They could hear a strange sound in the wind, like a far-away screaming. They put on their shawls and pinned them under their chins with their large shawl-pins. They put on their mittens.

Laura was ready first. She told Jack, "We've got to bring in wood, Jack." He seemed to understand. He went out with her and stayed close at her heels. The wind was colder than icicles. Laura ran to the woodpile, piled up a big armful of wood, and ran back, with Jack behind her. She could not open the door while she held the wood. Mary opened it for her.

Then they did not know what to do. The cloud was coming swiftly, and they must both bring in wood before the storm got there. They could not open the door when their arms were full of wood. They could not leave the door open and let the cold come in.

"I tan open the door," said Carrie.

"You can't," Mary said.

"I tan, too!" said Carrie, and she reached up both hands and turned the door knob. She could do it! Carrie was big enough to open the door.

Laura and Mary hurried fast, bringing in wood. Carrie opened the door when they came to it, and shut it behind them. Mary could carry larger armfuls, but Laura was quicker.

Text excerpt from **ON THE BANKS OF PLUM CREEK** by Laura Ingalls Wilder. Copyright, 1937, as to text, by Harper & Row, Publishers, Inc. Renewed 1965 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

They filled the woodbox before it began to snow. The snow came suddenly with a whirling blast, and it was small hard grains like sand. It stung Laura's face where it struck. When Carrie opened the door, it swirled into the house in a white cloud.

Laura and Mary forgot that Ma had told them to stay in the house when it stormed. They forgot everything but bringing in wood. They ran frantically back and forth, bringing each time all the wood they could stagger under.

They piled wood around the woodbox and around the stove. They piled it against the wall. They made the piles higher, and bigger.

Bang! they banged the door. They ran to the woodpile. Clop-clop-clop they stacked the wood on their arms. They ran to the door. Bump! it went open, and bang! they back-bumped it shut, and thumpity-thud-thump! they flung down the wood and ran back, outdoors, to the woodpile, and panting back again.

They could hardly see the woodpile in the swirling whiteness. Snow was driven all in among the wood. They could hardly see the house, and Jack was a dark blob hurrying beside them. The hard snow scoured their faces. Laura's arms ached and her chest panted and all the time she thought, "Oh, where is Pa? Where is Ma? and she felt "Hurry! Hurry!" and she heard the wind screeching.

The woodpile was gone. Mary took a few sticks and Laura took a few sticks and there were no more. They ran to the door together, and Laura opened it and Jack bounded in. Carrie was at the front window, clapping her hands and squealing. Laura dropped her sticks of wood and turned just in time to see Pa and Ma burst, running, out of the whirling whiteness of snow.

Pa was holding Ma's hand and pulling to help her run. They burst into the house and slammed the door and stood panting, covered with snow. No one said anything while Pa and Ma looked at Laura and Mary, who stood all snowy in shawls and mittens.

At last Mary said in a small voice, "We did go out in the storm, Ma. We forgot."

Laura's head bowed down and she said, "We didn't want to burn up the furniture, Pa, and freeze stark stiff."

"Well, I'll be darned!" said Pa. "If they didn't move the whole woodpile in. All the wood I cut to last a couple of weeks."

There, piled up in the house, was the whole woodpile. Melted snow was leaking out of it and spreading in puddles. A wet path went to the door, where snow lay unmelted.

Then Pa's great laugh rang out, and Ma's gentle smile shone warm on Mary and Laura. They knew they were forgiven for disobeying, because they had been wise to bring in wood, though perhaps not quite so much wood.

Reading Carefully

1. What did the Ingalls family use wood for?
2. What did Laura and Mary do that Ma and Pa had told them not to do? How did they feel about disobeying their parents?
3. We learn what people we know are like by seeing the way they act. Laura and Mary gave Ma and Pa different excuses for going outside. If this was all you knew about the girls, how would you describe their characters?
4. Why did Laura and Mary bring the wood into the house?
5. How did they know a blizzard was coming?
6. Words that sound like a sound they describe are called onomatopoeic words. They can add excitement when something is happening. Make a list of the onomatopoeic words in this story. In what part of the story are they used?

Thinking It Over

1. In your house, what takes the place of the wood the Ingalls used?
2. How does your family get ready for a storm or for winter?
3. Do you use more energy in your house when the weather is very cold? How do you know? What do you use the energy for?
4. What do you think the Ingalls family had to do to get fuel? What does your family have to do?
5. Tell about the time in your life when you were coldest.

Finding out More Information

1. Read Chapter 4, "October Blizzard," of **The Long Winter** by Laura Ingalls Wilder. How were the beans like the firewood? How were the walls of the house like the quilts?

Candlemaking

The end of butchering-time was candlemaking.

Mother scrubbed the big lard-kettles and filled them with bits of beef fat. Beef fat doesn't make lard; it melts into tallow. While it was melting, Almanzo helped string the candle-molds.

A candle-mold was two rows of tin tubes, fastened together and standing straight up on six feet. There were twelve tubes in a mold. They were open at the top, but tapered to a point at the bottom, and in each point there was a tiny hole.

Mother cut a length of candle-wicking for each tube. She doubled the wicking across a small stick, and twisted it into a cord. She licked her thumb and finger, and rolled the end of the cord into a sharp point. When she had six cords on the stick, she dropped them into six tubes, and the stick lay on top of the tubes. The points of the cords came through the tiny holes in the points of the tubes, and Almanzo pulled each one tight, and held it tight by sticking a raw potato ont he tube's sharp point.

When every tube had its wick, held straight and tight down its middle, Mother carefully poured the hot tallow. She filled every tube to the top. Then Almanzo set the mold outdoors to cool.

When the tallow was hard, he brought the mold in. He pulled off the potatoes. Mother dipped the whole mold quickly into boiling water, and lifted the sticks. Six candles came up on each stick.

Then Almanzo cut them off the stick. He trimmed the ends of wicking off the flat ends, and he left just enough wicking to light, on each pointed end. And he piled the smooth, straight candles in waxy-white piles.

All one day Almanzo helped Mother make candles. That night they had made enough candles to last till butchering-time next year.

Reading Carefully

1. What were the candles made out of? Why did candle making take place at the end of butchering-time?
2. What tools would you have to buy to make candles the way Mrs. Wilder did?
3. What were the potatoes used for?
4. When the candles had hardened, how did Mrs. Wilder get them out of the mold?

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Thinking It Over

1. Have you ever made candles? Tell about it.
2. Have you ever used candles in your household? When and why? In what ways was it better than electric light? In what ways worse? Were there any things you usually do by electric light that you couldn't do by candlelight?
3. How long did it take to make enough candles for a year? How many people helped? How many person days of labor does it take to provide your family with artificial light for a year? Do you think your family uses more artificial light than the Wilders did? Why?

Finding out More Information

1. Make some candles.
2. How many different non-electric ways of making light can be bought in your community? Compare their costs and advantages and disadvantages.

Icecutting

In this story, Almonzo goes with his father and brother to cut ice from a frozen lake. Lazy John and French Joe are two men who occasionally work for Almonzo's father.

He trudged with the others across the ice to the middle of the pond. A sharp wind blew there, driving wisps of snow before it. Above the deep water the ice was smooth and dark, swept almost bare of snow. Almanzo watched while Joe and John chopped a big, three-cornered hole in it. They lifted out the broken pieces of ice and carried them away, leaving the hole full of open water.

"She's about twenty inches thick," Lazy John said.

"Then saw the ice twenty inches," said Father.

Lazy John and French Joe knelt at the edge of the hole. They lowered their cross-cut saws into the water and began to saw. Nobody pulled the ends of the saws under water.

Side by side, they sawed two straight cracks through the ice, twenty inches apart, and twenty feet long. Then with the ax John broke the ice across, and a slab twenty inches wide, twenty inches thick, and twenty feet long rose a little and floated free.

With a pole John pushed the slab toward the three-cornered hole, and as the end was thrust out, crackling the thin ice freezing on the water, Joe sawed off twenth-inch lengths of it. Father picked up the cubes with the big iron ice-tongs, and loaded them on the bobsled.

Almanzo ran to the edge of the hole, watching the saw. Suddenly, right on the very edge, he slipped.

He felt himself falling headlong into the dark water. His hands couldn't catch hold of anything. He knew he would sink and be drawn under the solid ice. The swift current would pull him under the ice, where noboby could find him. He'd drown, held down by the ice in the dark.

French Joe grabbed him just in time. He heard a shout and felt a rough hand jerk him by one leg, he felt a terrific crash, and then he was lying on his stomach on the good, solid ice. He got up on his feet. Father was coming, running.

Father stood over him, big and terrible.

"You ought to have the worst whipping of your life," Father said.

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"Yes, Father," Almanzo whispered. He knew it. He knew he should have been more careful. A boy nine years old is too big to do foolish things because he doesn't stop to think. Almanzo knew that, and felt ashamed. He shrank up small inside his clothes and his legs shivered, afraid of the whipping. Father's whippings hurt. But he knew he deserved to be whipped. The whip was on the bobsled.

"I won't thrash you this time," Father decided. "But see to it you stay away from that edge."

"Yes, Father," Almanzo whispered. He went away from the hole, and did not go near it again.

Father finished loading the bobsled. Then he spread the laprobes on top of the ice, and Almanzo rode on them with Father and Royal, back to the ice-house near the barns.

The ice-house was built of boards with wide cracks between. It was set high from the ground on wooden blocks, and looked like a big cage. Only the floor and the roof were solid. On the floor was a huge mound of sawdust, which Father had hauled from the lumber-mill.

With a shovel Father spread the sawdust three inches thick on the floor. On this he laid the cubes of ice, three inches apart. Then he drove back to the pond, and Almanzo went to work with Royal in the ice-house.

They filled every crack between the cubes with sawdust, and tamped it down tightly with sticks. Then they shoveled the whole mound of sawdust on top of the ice, in a corner, and where it had been they covered the floor with cubes of ice and packed them in sawdust. Then they covered it all with sawdust three inches thick.

They worked as fast as they could, but before they finished, Father came with another load of ice. He laid down another layer of ice cubes three inches apart, and drove away, leaving them to fill every crevice tightly with sawdust, and spread sawdust over the top, and shovel the rest of the mound of sawdust up again.

They worked so hard that the exercise kept them warm, but long before noon Almanzo was hungrier than wolves. He couldn't stop work long enough to run into the house for a doughnut. All of his middle was hollow, with a gnawing inside it.

He knelt on the ice, pushing sawdust into the cracks with his mittened hands, and pounding it down with a stick as fast as he could, and he asked Royal,

"What would you like best to eat?"

They talked about spareribs, and turkeys with dressing, and baked beans, and crackling cornbread, and other good things. But Almanzo said that what he liked most in the world was fried apples'n'onions.

When, at last, they went in to dinner, there on the table was a big dish of them! Mother knew what he liked best, and she had cooked it for him.

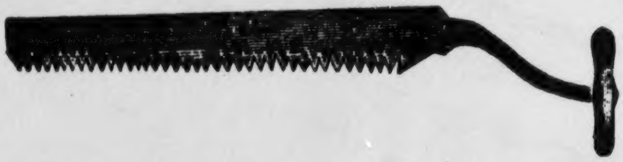
Almanzo ate four large helpings of apples'n'onions fried together. He ate roast beef and brown gravy, and mashed potatoes and creamed carrots and boiled turnips, and countless slices of buttered bread with crab-apple jelly.

"It takes a great deal to feed a growing boy," Mother said. And she put a thick slice of birds'-nest pudding on his bare plate, and handed him the pitcher of sweetened cream speckled with nutmeg.

Almanzo poured the heavy cream over the apples nested in the fluffy crust. The syrupy brown juice curled up around the edges of the cream. Almanzo took up his spoon and and ate every bit.

Then until chore-time he and Royal worked in the ice-house. All next day they worked, and all the next day. Just at dusk on the third day, Father helped them spread the last layer of sawdust over the topmost cubes of ice, in the peak of the ice-house roof. And that job was done.

Buried in sawdust, the blocks of ice would not melt in the hottest summer weather. One at a time they would be dug out, and Mother would make ice-cream and lemonade and cold egg-nog.



40201—Pond Ice Saws, set and sharpened, tapered from 7 inches to 5 inches at the point: complete with tiller handle, 4 feet long.

Each	$2.40
4½ feet long, each	2.70
5 feet long, each	3 00

Reading Carefully

1. How did they get the ice out of the lake?
2. How big was each block of ice?
3. How many different tools are mentioned in the story? Make a list.
4. What made Father angry? Did Almanzo think Father was right to be angry?
5. How did the Wilders carry the ice from the pond to their farm? Where did the energy to transport the ice come from?
6. What did the Wilders use as an insulator when they stored the ice? Where did they get it? What would have happened if they hadn't used an insulator? How thick a layer did they use?
7. What did the Wilders use the ice for?

Thinking It Over

1. Did you ever carry ice or other cold things to a picnic? How did you store them to keep them from melting?
2. If you were going to build an ice house today, what would you use as an insulator? How would you store the ice?
3. How many people for how many days were needed to provide the Wilder family with ice for a year? How many person-days of your family's labor are needed each year to provide your family with ice?
4. When do you use cold in your life? Would you miss it if you couldn't get it?

Talking About Horses

In **Farmer Boy**, Laura Wilder describes a visit Mr. Wilder and Almanzo make to the County Fair. Father and son are both very interested in seeing the horses.

Beyond them were large, speckled gray horses. Their haunches were round and hard, their necks were thick and their legs were heavy. Long, bushy hair hid their big feet. Their heads were massive, their eyes quiet and kind. Almanzo had never seen anything like them.

Father said they were Belgians. They came from a country called Belgium, in Europe. Belgium was next to France, and the French had brought such horses in ships to Canada. Now Belgian horses were coming from Canada into the United States. Father admired them very much. He said,

"Look at that muscle! They'd pull a barn, if hitched to it."

Almanzo asked him:

"What's the good of a horse that can pull a barn? We don't want to pull a barn. A Morgan* has muscle enough to pull a wagon, and he's fast enough to pull a buggy, too."

"You're right, son!" Father said. He looked regretfully at the big horses, and shook his head. "It would be a waste to feed all that muscle, and we've got no use for it. You're right."

*A Morgan is a kind of horse.

Reading Carefully

1. What did Father admire about the Belgians?
2. Why did Almanzo think the Belgians were not what they needed?
3. Father says "it would be a waste to feed all that muscle." What does he mean?

Thinking It Over

1. Would it have taken more energy for Mr. Wilder to use Belgians than to use Morgans? Why? What form would the energy be in? Would Mr. Wilder have gotten more useful work out of the Belgians?
2. What jobs might a Belgian be good for that you couldn't use a Morgan for?
3. In the 1880s, where did the energy to farm come from?
4. Rewrite this story as if it were 1980 and a boy and his father are in an automobile showroom looking at automobiles or trucks.
5. In a car, do you have to "feed all that muscle" as you do with a horse?

Finding out More Information

1. Read the sections on the Morgan, the Belgian, the Quarterhorse, and the Shire in **An Album of Horses,** by Marguerite Henry. What was each of these kinds of horse good for?
2. Read **Justin Morgan Had a Horse,** by Marguerite Henry, or **The Horse in America,** by Olive W. Burt.

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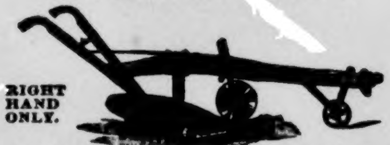
A New Plow

Pa had a new plow, a breaking plow. It was wonderful for breaking the prairie sod. It had a sharp-edged wheel, called a rolling coulter, that ran rolling and cutting through the sod ahead of the plowshare. The sharp steel plowshare followed it, slicing underneath the matted grass roots, and the moldboard lifted the long, straight-edged strip of sod and turned it upside down. The strip of sod was exactly twelve inches wide, and as straight as if it had been cut by hand.

They were all so happy about that new plow. Now, after a whole day's work, Sam and David gaily lay down and rolled, and pricked their ears and looked about the prairie before they fell to cropping grass. They were not being worn down, sad and gaunt, by breaking sod that spring. And at supper, Pa was not too tired to joke.

"By jingo, that plow can handle the work by itself," he said. "With all these new inventions nowadays, there's no use for a man's muscle. One of these nights that plow'll take a notion to keep on going, and we'll look out in the morning and see that it's turned over an acre or two after the team and I quit for the night."

Acme Prairie Breaking Plows.



Our Prairie Breaker combines many desirable qualities. Its construction is light and strong; the beam is adjustable; the shape is as near perfection as can be made; it turns a flat furrow with great ease and without breaking the sod; it is made with solid bar share, which is far superior to those formerly used on breakers. Shares are made to duplicate on all breakers. The many desirable qualities of this plow cannot help but bring it into great favor. **Shipped direct from factory in Northern Illinois.**

No. 32R249 Size, 12 inches; weight, 100 pounds; complete with rolling coulter, gauge wheel and extra share. Price................................**$9.85**

Reading Carefully

1. Why was the plow called a "breaking plow"?
2. Why were the girls happy about it? Why were Sam and David happy about it?

Thinking It Over

1. What benefit did Pa get from the new plow? What extra costs did Pa incur to get these benefits?
2. How have machines changed the relative importance of brain and muscle?

Text excerpt from **LITTLE TOWN ON THE PRAIRIE** by Laura Ingalls Wilder. Copyright, 1941, as to text, by Laura Ingalls Wilder. Renewed 1969 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

A Sewing Machine

"There's no flies on Clancy," said Pa. "He's got a machine to sew the shirts."

Ma was interested. "A sewing machine. Is it like that picture we saw in the "Inter-Ocean"? How does it work?

"About like I figured out it would," Pa answered. "You work the pedal with your feet, and that turns the wheel and works the needle up and down. There's a little contraption underneath the needle that's wound full of thread, too. Clancy was showing some of us. It goes like greased lightning, and makes as neat a seam as you'd want to see."

I wonder how much it costs,"said Ma.

"Way too much for ordinary folks," said Pa. "But Clancy looks on it as an investment, he'll get his money back in profits."

"Yes, of course, " Ma said. Laura knew she was thinking how much work such a machine would save, but even if they could afford it, it would be foolish to buy one for family sewing. "Does he expect Laura to learn how to run it?"

Laura was alarmed. She could not be responsible for some accident to such a costly machine.

Reading Carefully

1. Where did the energy to run Clancy's sewing machine come from?

2. Why wouldn't "ordinary folks" want one of the new machines, but Clancy would?

3. How did Mrs. Ingalls, way out on the frontier, know such a thing existed when she'd never seen one?

Thinking It Over

1. Today many families have sewing machines; they are not so expensive that only businesses can buy them. What made this possible?

2. For you, what takes the place of Ma's "Inter-Ocean?" Do you think you get more or less news than Ma did about things happening outside your everyday experiences? What has made this possible?

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Finding out More Information

1. Are foot-operated sewing machines still made? Who buys them? Where? Why?

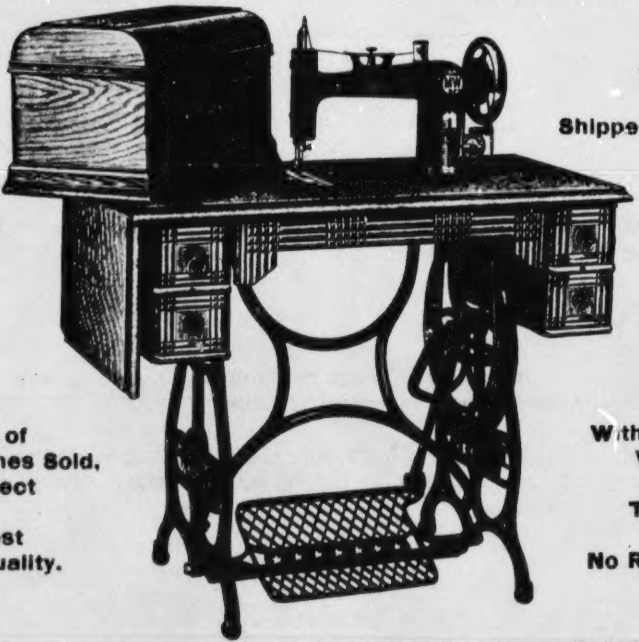
2. Learn how to sew a straight seam on a sewing machine. Is it easier to learn to operate a sewing machine or to learn how to make an equally good seam by hand?

3. Read pages 96-107 of **The Shores of Silver Lake**. These describe how the railroad men made the "grade" or bed that the railroad tracks were laid on. Then read, in **Little Town on the Prairie**, the description of when Laura went to work for the man who bought the sewing machine. What was similar about the sewing and the making of the grade?

4. Can you think of anything that only businesses think of owning today, but that families might own in the future? Explain why you think this will happen.

IMPROVED HIGH ARM SEWING MACHINE.

A Strictly High Grade Sewing Machine with All Modern Improvements. It has Few Equals. There are None Better. Ten Years Before The Public With a Record of 50,000 Machines Sold, All Giving Perfect Satisfaction. This is Our Best Evidence of Quality.



Warranted for 10 Years. Shipped Subject to a Thorough Trial. If Not Satisfactory Return at Our Expense, Both Ways, and We Refund Money Without Question. We Guarantee Safe Delivery. The Purchaser Assumes No Risk Whatever.

The above cut is an exact representation of Montgomery Ward & Co.'s High Arm Sewing Machine Nos. 5 and 5½.

OUR PRICES:

No. 5—Five drawers, as shown in cut, walnut woodwork	$19.50
No. 5½—Five drawers, as shown in cut, oak woodwork, very popular	$19.70
No. 6—Seven drawers, three on each side and center drawer, walnut woodwork	$20.50
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ABOVE STYLES, CRATED FOR SHIPMENT, WEIGH ABOUT 120 POUNDS EACH.

Mr. Ingalls Threshes

In this passage from **Little House in the Big Woods**, Laura Ingalls Wilder describes how a new machine came to thresh the wheat. Threshing separates the kernels of wheat from the wheat stalk and removes the chaff, a hull around each kernel. The wheat berries that are left are then ready to be ground into flour.

One frosty morning, a machine came up the road. Four horses were pulling it, and two men were on it. The horses hauled it up into the field where Pa and Uncle Henry and Grandpa and Mr. Peterson had stacked their wheat.

Two more men drove after it another, smaller machine.

Pa called to Ma that the threshers had come; then he hurried out to the field with his team. Laura and Mary asked Ma, and then they ran out to the field after him. They might watch, if they were careful not to get in the way.

Uncle Henry came riding up and tied his horse to a tree. Then he and Pa hitched all the other horses, eight of them, to the smaller machine. They hitched each team to the end of a long stick that came out from the center of the machine. A long iron rod lay along the ground, from this machine to the big machine.

Afterward Laura and Mary asked questions, and Pa told them that the big machine was called the separator, and the rod was called the tumbling rod, and the little machine was called the horsepower. Eight horses were hitched to it and made it go, so this was an eight-horsepower machine.

A man sat on top of the horsepower, and when everything was ready he clucked to the horses, and they began to go. They walked around him in a circle, each team pulling on the long stick to which it was hitched, and following the team ahead. As they went around, they stepped carefully over the tumbling rod, which was tumbling over and over on the ground.

Their pulling made the tumbling rod keep rolling over, and the rod moved the machinery of the separator, which stood beside the stack of wheat.

All this machinery made an enormous racket, rackety-banging and clanging. Laura and Mary held tight to each other's hand, at the edge of the field, and watched with all their eyes. They had never seen a machine before. They had never heard such a racket.

Pa and Uncle Henry, on top of the wheat stack, were pitching bundles down on to a board. A man stood at the board and cut the bands on the bundles and crowded the bundles one at a time into a hole at the end of the separator.

The hole looked like the separator's mouth, and it had long, iron teeth. The teeth were chewing. They chewed the bundles and the separator swallowed them. Straw blew out at the separator's other end, and wheat poured out of its side.

Two men were working fast, trampling the straw and building it into a stack. One man was working fast, sacking the pouring grain. The grains of wheat poured out of the separator into a half-bushel measure, and as fast as the measure filled, the man slipped an empty one into its place and emptied the full one into a sack. He had just time

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to empty it and slip it back under the spout before the other measure ran over.

All the men were working as fast as they possibly could, but the machine kept right up with them. Laura and Mary were so excited they could hardly breathe. They held hands tightly and stared.

The horses walked around and around. The man who was driving them cracked his whip and shouted, "Giddap there, John! No use trying to shirk!" Crack! went the whip. "Careful there, Billy! Easy, boy! You can't go but so fast nohow."

The separator swallowed the bundles, the golden straw blew out in a golden cloud, the wheat streamed golden-brown out of the spout, while the men hurried. Pa and Uncle Henry pitched bundles down as fast as they could. And chaff and dust blew over everything. Laura and Mary watched as long as they could.

Then they ran back to the house to help Ma get dinner for all those men.

A big kettle of cabbage and meat was boiling on the stove; a big pan of beans and a johnny-cake were baking in the oven. Laura and Mary set the table for the threshers. They put on salt-rising bread and butter, bowls of stewed pumpkin, pumpkin pies and dried berry pies and cookies, cheese and honey and pitchers of milk.

Then Ma put on the boiled potatoes and cabbage and meat, the baked beans, the hot johnny cake and the baked Hubbard squash, and she poured the tea.

Laura always wondered why bread made of corn meal was called johnny-cake. It wasn't cake. Ma didn't know, unless because the people in the South, where they fought, ate so much of it. They called the Southern soldiers Johnny Rebs. Maybe, they called the Southern bread, cake, just for fun.

Ma had heard some say it should be called journey-cake. She didn't know. It wouldn't be very good bread to take on a journey.

At noon the threshers came in to the table loaded with food. But there was none too much, for threshers work hard and get very hungry.

By the middle of the afternoon the machines had finished all the threshing, and the men who owned them drove them away into the Big Woods, taking with them the sacks of wheat that were their pay. They were going to the next place where neighbors had stacked their wheat and wanted the machines to thresh it.

Pa was very tired that night, but he was happy. He said to Ma:

"It would have taken Henry and Peterson and Pa and me a couple of weeks apiece to thresh as much grain with flails as that machine threshed today. We wouldn't have got as much wheat, either, and it wouldn't have been as clean.

"That machine's a great invention!" he said.

"Other folks can stick to old-fashioned ways if they want to, but I'm all for progress. It's a great age we're living in. As long as I raise wheat, I'm going to have a machine come and thresh it, if there's one anywhere in the neighborhood."

He was too tired that night to talk to Laura, but Laura was proud of him. It was Pa who had got the other men to stack their wheat together and send for the threshing machine, and it was a wonderful machine. Everybody was glad it had come.

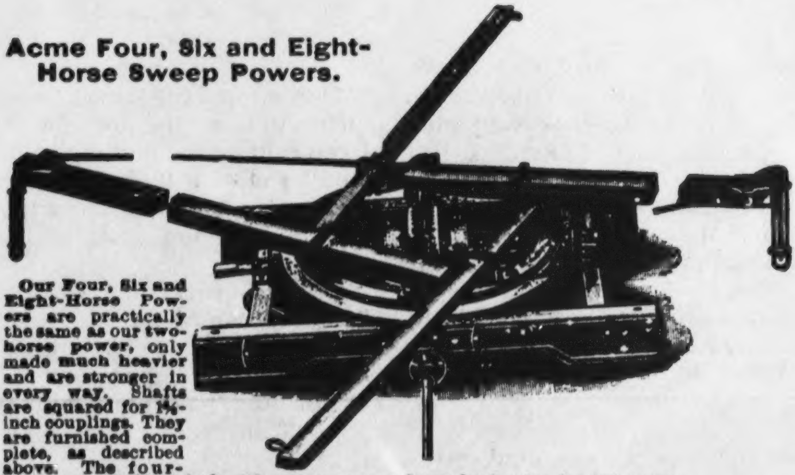
Reading Carefully

1. What time of year was it? How do you know?
2. Draw a rough picture of the threshing machine. Label the parts with the names given in the story.
3. How many "horsepower" was the threshing machine? Where did the energy to run the threshing machine come from? (Follow it back to sunlight.)
4. Do you think using the threshing machine was hard work or an easy job? Why? How many men did it take to run the machine and what did they do?
5. How did Mr. Ingalls feel about the machine?
6. Why was Laura proud of her father?

Thinking It Over

1. In the story, Pa guesses how long it would have taken to thresh the wheat with flails. How many days of labor did the threshing machine save? (Remember, Pa and the other men wouldn't have worked on Sunday.)
2. From the information in the story, make an estimate of how many bushels of wheat the men threshed that day. Show how you calculated it. (Hint – pretend you are sacking half-bushels of wheat, and time yourself with a clock.)
3. What kinds of changes might the threshing machine have made in the lives of wheat farmers like the Ingalls?
4. Pretend you are a horse. Write a paragraph for the "Horse News" describing the new machine from a horse's point of view.
5. Pretend you were a young person at a time when another labor-saving machine was introduced. Write a story about the first time you saw the machine work. Tell where the energy to run the machine came from.

Acme Four, Six and Eight-Horse Sweep Powers.



Our Four, Six and Eight-Horse Powers are practically the same as our two-horse power, only made much heavier and are stronger in every way. Shafts are squared for 1¾-inch couplings. They are furnished complete, as described above. The four-horse power is furnished with two sweeps and two lead poles for two teams, high speed 51 revolutions, low speed 10¼ revolutions to one round of the horses. If wanted with four sweeps, price will be same as for six-horse power. Shipped direct from factory to user.

No. 32R1813 Four-Horse Power. Weight, 1000 pounds. Price....$27.40

No. 32R1814 Six-Horse Power, furnished with four sweeps and speeded same as four-horse power. Weight, 1100 pounds. Price..................$32.40

No. 32R1815 Eight-Horse Power, furnished with four sweeps. High speed 65 revolutions, low speed 12¼ revolutions to one round of the horses. Weight, 1400 pounds. Price....... .... $43.15

Mr. Wilder Threshes

In the book **Farmer Boy**, Laura Ingalls Wilder describes the boyhood of the man she eventually married, Almanzo Wilder. Almanzo grew up on a prosperous farm in upper New York State near the Saint Lawrence River. This region had been settled for several hundred years and the Wilder family's life represented up-to-date conventional farming, not pioneering the wilderness. Almanzo's father didn't share Mr. Ingalls' feeling about threshing machines.

The flail had come off its handle and Father had put them together again. The flail was an ironwood stick, three feet long and as big around as a broom-handle. It had a hole through one end. Its handle was five feet long, and one end was a round knob.

Father put a strip of cowhide through the hole in the flail, and riveted the ends together to make a leather loop. He took another strip of cowhide and cut a slit in each end of it. He put it through the leather loop on the flail, then he pushed the slits over the knobbed end of the handle.

The flail and its handle were loosely held together by the two leather loops, and the flail could swing easily in any direction.

Almanzo's flail was just like Father's, but it was new and did not need mending. When Father's flail was ready, they went to the South-Barn Floor.

There was still a faint smell of pumpkins, though the stock had eaten them all. A woodsy smell came from the pile of beech leaves, and a dry, strawy smell came from the wheat. Outside the wind was screeching and the snow was whirling, but the South-Barn Floor was warm and quiet.

Father and Almanzo unbound several sheaves of wheat and spread them on the clean wooden floor.

Almanzo asked Father why he did not hire the machine that did threshing. Three men had brought it into the country last fall, and Father had gone to see it. It would thresh a man's whole grain crop in a few days.

"That's a lazy man's way to thresh," Father said. "Haste makes waste, but a lazy man'd rather get his work done fast than do it himself. That machine chews up the straw till it's not fit to feed stock, and it scatters grain around and wastes it.

"All it saves is time, son. And what good is time, with nothing to do? You want to sit and twiddle your thumbs, all these stormy winter days?"

"No!" said Almanzo. He had enough of that, on Sundays.

They spread the wheat two or three inches thick on the floor. Then they faced each other, and they took the handles of their flails in both hands; they swung the flails above their heads and brought them down on the wheat.

Father's struck, then Almanzo's, then Father's, then Almanzo's. Thud! Thud! Thud! Thud! It was like marching to the music on Independence Day. It was like beating the drum. Thud! Thud! Thud! Thud!

Text excerpt from **FARMER BOY** by Laura Ingalls Wilder. Copyright, 1933, as to text, by Harper & Row, Publishers, Inc. Copyright renewed ©1961 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

The grains of wheat were shelling from their little husks and sifting down through the straw. A faint, good smell came from the beaten straw, like the smell of the ripe fields in the sun.

Before Almanzo tired of swinging the flail, it was time to use the pitchforks. He lifted the straw lightly, shaking it, then pitched it aside. The brown wheat-grains lay scattered on the floor. Almanzo and Father spread more sheaves over it, then took up their flails again.

When the shelled grain was thick on the floor, Almanzo scraped it aside with a big wooden scraper.

All that day the pile of wheat grew higher. Just before chore-time Almanzo swept the floor in front of the fanning-mill. Then Father shoveled wheat into the hopper, while Almanzo turned the fanning-mill's handle.

The fans whirred inside the mill, a cloud of chaff blew out its front, and the kernels of clean wheat poured out of its side and went sliding down the rising heap on the floor. Almanzo put a handful into his mouth; they were sweet to chew, and lasted a long time.

He chewed while he held the grain-sacks and Father shoveled the wheat into them. Father stood the full sacks in a row against the wall – a good day's work had been done.

Reading Carefully

1. What was the flail made out of? How big was it? How many pieces did it have? Draw a picture of it.
2. With a partner, pretend you are flailing wheat. Go through all the motions you think Almanzo would, starting with getting the sheaves.
3. Why wouldn't Mr. Wilder use a threshing machine?
4. Where did the energy to thresh the Wilder's wheat come from?
5. Thud! Thud! Thud! Laura Wilder often uses words that sound like a sound. These words are called onamatopoeic words. Can you find another one in the story?

Thinking It Over

1. Can you find any evidence in the description of the threshing at the Ingalls' that would support Mr. Wilder's criticism of the threshing machine?

2. What do you think? Who was right, Mr. Ingalls or Mr. Wilder? Was the thresher a good idea? Would you have used it?

Finding out More Information

1. How is wheat threshed today? Where does the energy to do the threshing come from?
2. Even Mr. Wilder uses a machine, the fanning-mill, to separate the wheat from the chaff. What did people do before there were fanning-mills?
3. Read Chapter 11, "Springtime," in **Farmer Boy,** and Chapter 2, "Springtime on the Claim," in **Little Town on the Prairie.** These chapters describe how farmers in those days prepared the ground and planted the seed. Describe how they did it and where the energy used came from.
4. Read Chapter 25, "The Glittering Cloud," in **On the Banks of Plum Creek.** How did the Ingalls try to cope with the problem described in this chapter? How do farmers cope today? How has the change caused a change in farmers' energy consumption?

Lead Time: A Puzzle For Planners

Objectives

This lesson contributes to the students' understanding of the following ideas:

Years or decades are required to plan and build major energy installations; there are limits to how fast this process can be speeded up whatever the urgency.

Because of lead time requirements, we are deciding now what major energy facilities will be available in the 1990's.

Methods can be worked out for determining the fastest way of building a major facility.

Increasing lead times mean increases in the costs of building a facility, because of the interest on the capital that is not yet productive.

Format of the Lesson

More than one class period is needed for this lesson, since students need to take the second worksheet home and puzzle over it.

Preliminary discussion of "doing things"

Pass out worksheet, **Baking a Cake**

Silent work period

Class review of solution on chalkboard

Arrange class in groups

Pass out worksheet, **Lead Time, a Puzzle for Planners**

Silent work period; teacher circulates

Subsequent Periods

Supervised group work

Presentation and discussion of results

Calculation of effect of increasing lead time on interest costs

Historical data

Materials Needed

activity sheet **Baking a Cake,** one for each student.

activity sheets **Lead Time, a Puzzle for Planners,** one set per student.

scratch paper, pencils and erasers, Scotch® tape.

overhead transparency, puzzle solution.

Teacher Background

Students, like the general public, often fail to appreciate how long it takes to plan and build any large energy installation, such as a refinery, power station, or even a factory for solar collectors. To have electricity from a new power station available for today's seventh graders when they graduate from college, a commitment to build the plant must be made now. So we are making our energy decisions for the 1990's right now. We will not be able to change our minds later and create instant capital equipment in a crash program.

Lead time for electric power stations has been lengthening; more so in this country than abroad. One reason for this are new environmental concerns and the way these concerns have been embodied in legislation. Expansion of lead times also increases the cost of the plant (and so the cost of the electricity it produces), because it increases the length of time money is out before it starts earning a return. (Utilities are not ordinarily allowed to add the cost of a new station to their "rate base" until it is in operation and actually supplying electricity to customers).

Preliminary Discussion

Ask students if they ever made something that took planning ahead, such as a special dinner or a model airplane, or helped a parent install something. Encourage the students to talk about what they did.

Question students who respond to bring out that most projects involve a number of separate tasks. One way to do this is by summarizing the student's description: "O.K., let me get this straight. First you, then you, then you..."

Go back and ask students if they had any idea before they began their project how long it would take. How did they make their estimate?

Summarize that many projects involve a number of different tasks that have to be done in some order, more or less. Part of planning how to do something is knowing what to do, but also knowing what order to do things in and how long it will take to do.

Tell the class we're going to work on a puzzle. We're going to try to figure out how long it takes to do something if you know how long all the individual parts of the job would take.

The "cake" activity is provided as preparation for the more difficult activity that follows. It gives students an opportunity to become familiar with the charting technique by practicing it on a simple familiar project before considering a more complex one.

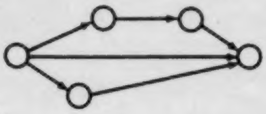
Baking a Cake

Pass out the **Baking a Cake** worksheet and suggest students look it over. Ask for a show of hands on how many people have ever helped bake a "scratch" cake.

Tell students this is a list of things to do to make a cake. We want to make a chart to show in what order we do these things. To do this, we'll identify the jobs by the numbers given them on the sheet. What number would we begin with? (ANS: 14, recipe.) Write 14 in a circle on the left hand side of the chalkboard. What number will we end with? (ANS: 17, eating the cake.)

Draw a circle next to the right of the 14 circle and connected to it by a line. State that this would represent the next thing we'd have to do. What would that be? (ANS: 4, buy the ingredients.)

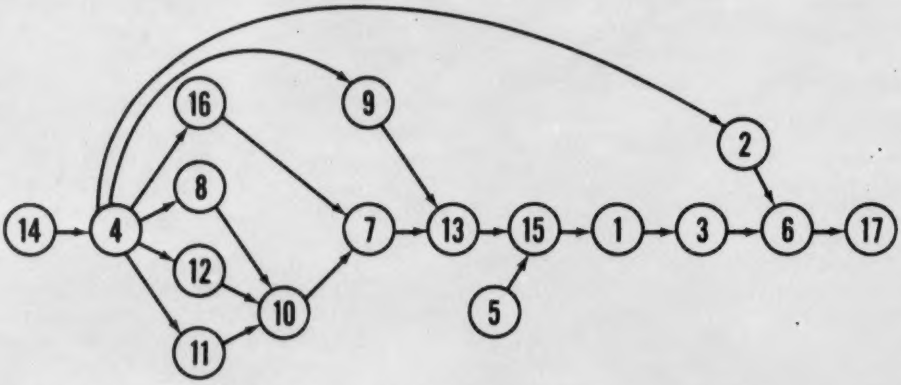
Ask the class to take out paper and pencil and make a complete path from 14 to 17, including all the steps. Mention it won't be a straight line because sometimes you may be doing three things at once, so you could do something like this. Draw a disconnected branch in the middle of the board, viz,



then erase it. While the students are working, circulate to help those who are having trouble.

Class Review of Solution

The solution looks like this:



duration of lengthiest task in each leg
20m 45m 10m 5m 15m 0m 45m 0m 20m 10m 0m

elapsed time since start of project
20m 1h5m 1h15m 1h20m 1h35m 2h20m 2h40m 2h50m

Elicit it number by number from the class, drawing it on the chalkboard as you go.

When the chart is completed and the students understand how it was created, discuss the time factor. This is straightforward except for getting from 4 to 7, because there are four different paths, 4-16-7, 4-8-10-7, 4-12-10-7, and 4-11-10-7. Help students see that getting from 4 to 7 will take as long as it takes to do the lengthiest set of tasks between four and seven. Because task twelve takes longer than tasks eight or eleven, the length of time it takes to do the path 4-12-10-7 will be the length of time it takes to get from four to seven.

Calculate the time required from the chart, using the longest time between any two points.

Now divide the class into groups and arrange the room appropriately if necessary.

Lead Time

Pass out the worksheet, **Lead Time: A Puzzle for Planners.** Ask the students to solve this problem as they did the earlier one.

This is obviously a far more difficult problem than the cake. Simply reading the tasks may consume most of the time remaining in the period.

When the students first begin to work on the chart, an adult resource should be available. A helpful way of getting started is to make a chart by taping together pieces of ruled paper. Let each line represent a month. Start at the end and work backwards, making liberal use of an eraser. Monitor the progress of groups to determine when it will be appropriate to begin the class review.

Reviewing the Rules

Ask who has been able to do the job in the least number of months. Take the team with the least number of months and have them put their chart on the board, month by month, asking the class if it agrees the solution is possible. It is impossible to predict how long this will take because classes vary greatly in the frequency and accuracy of objections raised to the solution. On the next page is the fastest plan we could work out.

Conclude by asking if anyone has any improvements to add. Your chart should then look something like ours, but it isn't important that it be an exact dupliduplicate.

A master for making an overhead transparency of the solution is provided, to save the tedious job of copying it onto the board.

Computing the Interest

Notice along the bottom of the chart are two lines of figures. The first line shows the amount of money spent that year. The second shows the cumulative total. There are some interesting facts to be noted about these series of figures.

First, notice that expenditures in early years are much lower than in later years. The money really starts to flow when large numbers of workers are added and heavy equipment is purchased.

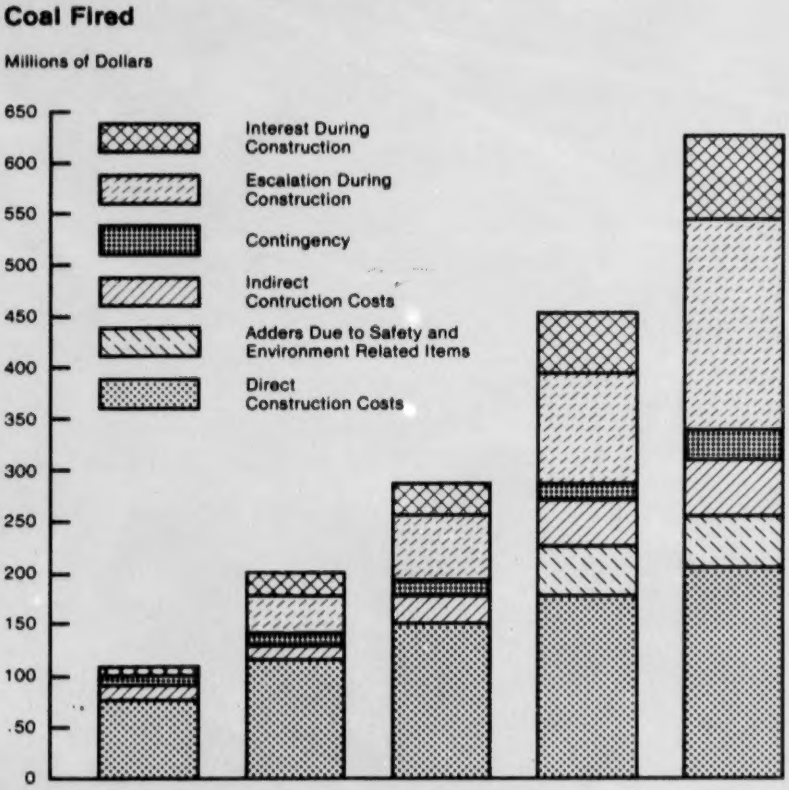
Point out that the money spent on construction does not begin to earn money until the plant begins to generate electricity. Calculate what the interest in some of the years would be at the current prime rate.

Here is a trick question: if one plant costs $900 million in labor and materials to build and takes five years, and another costs $900 million and takes 10 years, which costs more? The second costs more because you will have to pay five extra years' interest.

Some Historical Data

So that the students can see the practical application of what they've been doing, here are some figures you can share with them on the escalation of lead times and interest expenses over the past ten years.

Comparison of Plant Cost Estimates
(Total Investment for 1000 MWe Plants)



EVALUATION:		WASH-1150	WASH-1230	WASH-1230 REVISED	WASH-1230 REVISED
EXPERIENCE:	1966	JUNE 1969	JAN. 1971	JAN. 1973	JAN. 1973
COST BASIS:	MARCH 1967	JUNE 1969	JAN. 1971	JAN. 1973	JULY 1974
COMMERCIAL OPERATION:	LATE 1972	MID-1975	JAN. 1978	JAN. 1981	JAN. 1983

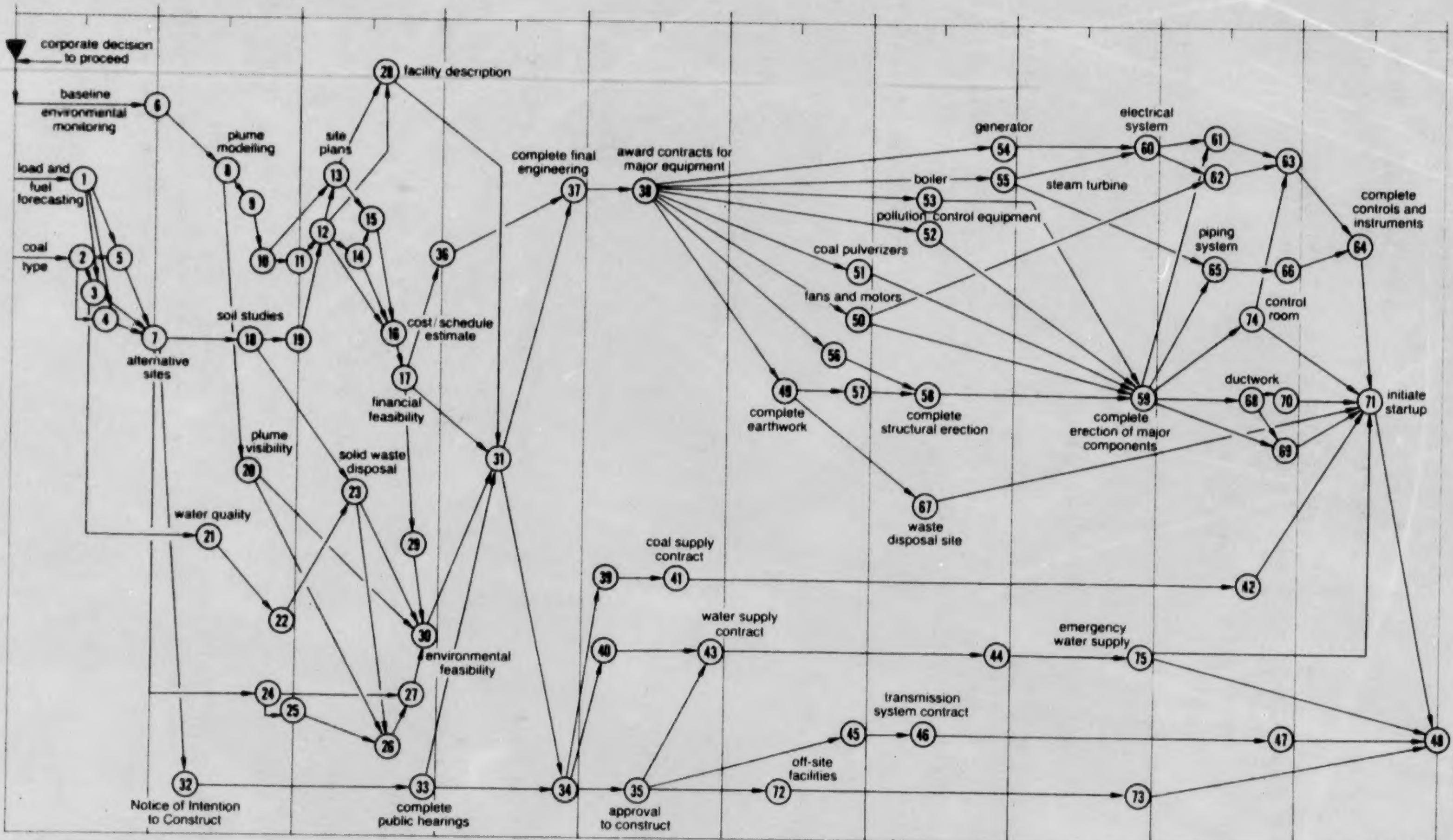
Baking a Cake

You are baking a cake for company with the help of two friends. Because there are three of you, you can do more than one thing at a time. The cake must be ready by six o'clock. If you have to do all the steps below (which aren't in any order), when will you have to start in order to finish by six?

1. Remove cake from oven. Can't be done until cake is baked.
2. Mix frosting. Takes ten minutes. Can't be done until ingredients have been bought.
3. Remove cake from pan, place on wire rack, and let cool. Takes twenty minutes, can't be done until cake is out of oven.
4. Go to store and buy ingredients. Takes 45 minutes, can't be done until recipe is selected.
5. Preheat oven. Takes five minutes.
6. Frost cake. Takes 10 minutes, can't be done until frosting is mixed and cake is cool.
7. Combine wet and dry ingredients and beat for 100 strokes. Takes 15 minutes. Can't be done until milk, shortening and eggs have been combined and dry ingredients have been sifted.
8. Measure milk. Takes 5 minutes, can't be done until ingredients have been purchased.
9. Grease and flour baking pans. Takes 5 minutes, can't be done until ingredients have been purchased.
10. Combine milk, shortening, and eggs. Takes 5 minutes, can't be done until eggs have been beaten, milk has been measured, and shortening has been melted.
11. Beat eggs. Takes five minutes, can't be done until ingredients have been purchased.
12. Melt and measure shortening. Takes 10 minutes, can't be done until ingredients have been purchased.
13. Pour batter into baking pans. Can't be done until wet and dry ingredients have been mixed and pans have been greased.
14. Look through cookbooks and select recipe for cake. Takes 20 minutes. Do this first.
15. Put cake in oven and bake for forty-five minutes. Can't be done until oven is preheated and batter has been poured into pans.
16. Measure and sift flour and other dry ingredients. Takes ten minutes, can't be done until ingredients are purchased.
17. Eat the cake.

Tasks Required for Construction of a 1000 MWe Coal-fired Powerplant

Years from start of project


corporate decision to proceed
baseline environmental monitoring
load and fuel forecasting
coal type
alternative sites
plume modelling
site plans
facility description
soil studies
cost/schedule estimate
financial feasibility
plume visibility
solid waste disposal
water quality
environmental feasibility
Notice of Intention to Construct
complete public hearings
complete final engineering
award contracts for major equipment
generator
boiler
steam turbine
pollution control equipment
coal pulverizers
fans and motors
complete earthwork
complete structural erection
waste disposal site
electrical system
piping system
control room
ductwork
complete erection of major components
complete controls and instruments
initiate startup
coal supply contract
water supply contract
emergency water supply
transmission system contract
off-site facilities
approval to construct
deliver firm commercial power to electrical grid
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75

Annual Expenditure (in millions)	$20	$50	$50	$80	$150	$250	$300	$250	$200	$100
Cumulative Expenditure (in millions)	$20	$70	$120	$200	$350	$600	$900	$1150	$1350	$1450

Note: a 1980 start date is assumed, with costs (including AFDC) in 1980 dollars.

Lead Time: A Puzzle For Planners

You are planners for a large electric utility. Your job is to decide when to begin constructing new power plants to meet increasing demand for electricity. Conservation and load management measures, including new time-of-day power meters, have successfully reduced the increase in peak demand for your electricity to 2% per year. Your electrical system does not contain old plants that it would be practical to renovate or repower.

You cannot buy electricity from neighboring utilities. They are all facing power shortages too and are already asking to purchase power from you.

You have looked into what fuels might be available in the future. After a long and stormy debate within the company, top management has decided to build a large coal-fired power plant, to be operating by the time that you predict extra power will be needed.

As planners, you have tried to predict how much electricity your customers will want in future years, and have compared that with your estimate of what generating equipment will be available. This forecast shows that the difference between generating capacity and projected peak demand is expected to drop to a dangerous level (below 10%) after 1990. This means that by 1990, more than 90% of all your existing facilities must be operating at full load (including plants which must be shut down for maintenance). If they aren't, your company must turn off the electricity, causing a rolling blackout during periods of peak demand.

In order to minimize the risk of power shortages or rolling blackouts, you recommend that a 1000 MWe coal-fired power plant be constructed by 1990.

Management asks two questions:

1. When do we need to start obtaining permits and building the plant, so that it will be running by 1990?
2. How many new power plants do we have to start building to meet the forecasted electrical demand before the first plant actually begins operating (and earning money) in 1990?

As chief planner, you have requested scheduling information from people who work for you. They have come up with 75 tasks. Now you need to put these tasks in the form of a network (as you did with "Baking a Cake"), so that the total time required for the project can be determined. (Hint: Try using ruled 8½ × 11 paper, turned sideways, making every line equal to one month. Tape several sheets together to make one long skinny piece with vertical lines. Do your work in pencil. If you have trouble getting started, try beginning with the completion of the plant in 1990 and working backwards.)

Building a Coal-Fired Power Plant: Jobs That Have to be Done

This is a list of tasks that would have to be done to build a coal-fired powerplant. (We've assumed the studies at the beginning would show coal was the best fuel for the circumstances.) For each task, an estimate of the number of months it would take is also given. These estimates are educated guesses based on times required in 1979, and also assume a plant size of 1000 MWe. This is less than ½ of 1% of the current coal-fired capacity in the USA. Considering that we don't know where the plant will be, what the air pollution requirements are, how far away the mine is, and so on, the estimates are as realistic as possible.

The tasks are not necessarily listed in the order that they would be done.

	Months	**Tasks We Have to Finish First**
1. The utility estimates how much electricity it will be expected to supply in 1990. It also estimates how much fuel will be required to produce the electricity and whether it will be available. Begin as soon as the utility company decides to go ahead.	6	"go ahead" decision
2. Find a source of coal. In the laboratory, test samples of the coal to find out how many Btu's it produces per ton, how much sulfur is in it, how much slag it produces, and other things you need to know to design the plant. Can't begin until the utility company makes a decision to go ahead.	6	"go ahead" decision
3. Water is needed to run a fossil-fuel plant. The utility searches the region where the plant might be located to find possible sources for the amount of water needed.	1	1, 2
4. A power plant needs paths for coal and equipment to get to the plant and for electricity and wastes to leave. The utility company examines the region to see where transmission line corridors, railroad tracks, slurry pipelines, solid waste disposal areas, and road might be put.	2	1, 2

	Months	Tasks We Have to Finish First
5. The people who will operate the plant have to live somewhere; they need permanent homes, and the people who build the plant will need temporary homes. They will need water, schools, roads, food stores, and a lot of other things. The utility estimates how many people will be required, what they will need, and how able the reion would be to provide the services the people need.	3	1, 2
6. In order to know whether the plant has caused any changes in the environment, we need a record of exactly what the environment was like before the plant was built. The utility sends out scientists to spend a year measuring the environment in the region where the plant will be built. Begin as soon as the utility company decides to go ahead.	12	"go ahead" decision
7. Now we know something about the region's human and physical resources, and its environment. The law requires the utility to select three possible choices of a site for the power plant. The utility now purchases the sites or otherwise obtains the right to use of the land.	3	3, 4, 5
8. Pollutants can be carried downwind from a power plant in the "smoke" from the plant. We need to know where this smoke will go and how concentrated it will be at all locations. To predict this, the utility uses a computer to process information on the size of the plant, the weather conditions, and even the hills and valleys surrounding the sites.	6	6
9. The utility's engineers calculate how high the smokestack should be and what kind of pollution control equipment will be needed to prevent significant deterioration of the air quality at ground level downwind.	2	8
10. The allowable smokestack emissions from each of the three sites will be a little different. The utility makes a first rough estimate of how those differences would affect a power plant.	1	9

	Months	Tasks We Have to Finish First
11. Now the engineers who will design the plant need to get a rough idea on the size of the flows of energy and material through the plant. They do this by preparing flow diagrams that show where everything comes from and where it goes.	3	10
12. Using the flow diagram, the engineers figure out roughly how big all the major pieces of equipment (like the boiler) will be and their shapes.	2	11 and 19
13. For each of the three sites, the utility prepares a map showing where the buildings and roads would be.	1	10 and 12
14. Some of the pieces of equipment needed will take a long time to make, especially if manufacturers already have a lot of orders and we must wait our turn. The utility makes a shopping list of everything which will take a long time to obtain.	3	12
15. To begin planning how the contractor will build the plant, the utility makes a rough estimate of the order in which the largest pieces of equipment will have to be installed.	1	13 and 14
16. For each of the three possible sites, we need to prepare a rough estimate of costs and schedule.	2	12, 14, 15
17. Now that we have a better idea of what would be involved in building on each of the three sites, the utility company accountants can compare how expensive it would be to build and operate a plant at each of the three sites.	1	16
18. To build foundation strong enough to support something as heavy as a powerplant, you need a good idea of what the ground underneath is like: how far down bedrock is, whether there are earthquake faults nearby, and so on. To find out, the utility geologists drill holes and conduct field studies.	8	7
19. Now that we know the geology of the ground we're building on, the utility's engineers can make a rough design of each foundation.	4	18

	Months	Tasks We Have to Finish First
20. We don't want the plant to be an eyesore. The structures should fit the setting and the plume should not be too visible. This is harder to achieve in some places than others; the utility evaluates the three possible sites for aesthetic factors.	2	8
21. The three sites may not have the same water. Some water may have more minerals than others, or the water may dry up at certain seasons. The utility investigates the water supply at each site.	10	3
22. The plant will produce some liquid wastes. To minimize the amout of liquid waste, the utility hires process engineers to study how to reuse salty water and avoid buildup of harmful deposits inside the plant.	6	21
23. Burning coal leaves ashes, and the ashes contain some harmful trace elements. The utility plans what it will do with the ashes and studies whether, for example, rainfall will wash harmful materials out of the ashes into rivers or the watertable.	6	18 and 22
24. For each of the three sites, utility planners figure out how many workers would be needed and what community developments would be needed to support them.	10	7
25. For each of the three possible sites, utility engineers determine all the transportation improvements that would be needed (roads, railroad tracks and sidings, piplines, powerline corridors, and so forth).	2	24

	Months	Tasks We Have to Finish First
26. The utility hires archeologists, biologists, and other experts to evaluate the effect constructing and operating the plant will have on historic and archeological features, on wildlife, including vegetation, on other forms of land use by humans, and so forth, at each of the three possible sites.	3	20, 23, 25
27. The utility hires sociologists to predict what effect construction of the power plant at each of the three possible sites would have on the life of the people in the region.	2	24 and 26
28. The utility's engineers pull the engineering information together and make a complete description of the powerplant for each of the three possible sites.	4	12 and 13
29. The utility hires economists to make a study of the effect the power plant will have on the economy of the region.	1	17
30. The engineers have determined, for each site, approximately what a plant meeting current environmental regulations would be like. Now the utility's cost analysts determine which of the three sites is the most feasible in terms of paying back the money required to build the plant.	1	20, 23, 27 and 29
31. The economic and environmental feasibility of the three sites are compared in the Final Environmental Impact Statement, and a single site is recommended. For a typical power plant, this will be a set of three-ring binders about three feet high.	6	17, 28, 30 and 33
32. The utility submits a *Notice of Intention to Construct* a coal-fired power plant to government agencies. This starts the regulatory review process.	3	7

	Months	Tasks We Have to Finish First
33. The utility staff fills out the necessary forms and provides information. The government agencies hold public hearings and examine the information to determine whether building the plant will be in the public interest and will conform to legal requirements. Among the interested agencies would be:	20	32

Federal

- Department of Energy
- Environmental Protection Agency
- OSHA (Occupational Safety and Health Administration)
- Department of Interior (USBR, Park Service, etc. as appropriate)
- Federal Bureau of Mines
- Department of Agriculture (Forest Service, Bureau of Land Management, as appropriate)
- Department of Transportation (ICC, FAA, FCC, Federal Highway Commission, Federal Railway Commission, etc. as appropriate

State

- Public Utilities Commission
- Air Resources Conservation Commission
- Water Conservation Authority
- Department of Fish and Game
- Park and Wildlife Commission(s)
- Soil Conservation Authority
- Department of Highways

County

- Air Pollution Control District
- Building Permits
- Sanitary Landfill Permits

	Months	Tasks We Have to Finish First
34. The key regulatory agencies give their preliminary approval. To save time, the utility sends various manufacturers a shopping list describing the major pieces of equipment it wants to buy, and asks them "how much?"	6	31 and 33
35. Government agencies complete their study of the project and grant final approval.	6	34
36. The utility selects an engineering-construction company to design and construct the power plant.	3	17
37. The engineers complete most of the final design and prepare a description of the major items that will need to be made to order (like boilers, pumps, transformers, and so forth).	6	31 and 36
38. Manufacturers who are interested in supplying equipment study the bid specifications and decide how much money they would ask to build the items. They issue quotes to the utility, who reviews and selects a manufacturer the best suited to do the work. Contracts are signed as soon as the utility receives final regulatory approval.	6	37
39. The utility and the company who will supply the coal work out an agreement about quantity and quality of coal, delivery schedules, and price.	3	34
40. The utility negotiates a price with whoever has water rights.	3	34
41. The coal supplier will have to increase the amount of coal it can mine each day in order to provide the new amounts needed for the new power plant. The mine may need more equipment, more transportation facilities like railroad sidings, drag lines, new mineshafts, and so on. (Note - the mine will probably have to go through the same engineering and issuing of bids to manufacturers that the utility did for the power plant. It will also have to obtain the approval of government regulatory agencies. It is assumed that regulatory approval for expansion of coal mining and transportation facilities have been obtained with the power plant approval process.)	6	39

	Months	Tasks We Have to Finish First
42. The coal supplier begins delivering coal to the powerplant site. On the site, the contractor prepares a place for holding a pile of coal big enough to keep the powerplant operating during an interruption of coal deliveries. The first deliveries of coal will be used to build up this stock pile.	48	41
43. Whoever will be supplying the water (it may be the utility itself or it may be another company or agency) issues contracts to construct facilities to supply and store the water, such as pipelines, reservoirs, intake structures if the water is being drawn from a river, and so on.	6	35 and 40
44. Pipelines are constructed and water starts coming to the site.	24	43
45. A team of negotiators from the utility completes the task of buying rights-of-way for the transmission corridors and other pieces of land needed besides the powerplant site itself.	18	35
46. The utility awards a contract to a construction company to put up the transmission line and the switchyard.	6	45
47. The construction company puts up all the towers for the transmission lines, strings the cable, and tests the system.	30	46
48. The plant operators spend six months starting up the equipment and adjusting all the controls. Complete testing on air and water is followed by lighting off the boiler and eventually bringing all the systems to full operating capacity. When this work is completed, the plant goes "commercial" and begins supplying electricity on a regular, reliable basis.	6	47, 71, 73 and 75
49. With bulldozers and other earthmoving machinery, the contractor grades the entire powerplant site according to plans.	12	38

	Months	Tasks We Have to Finish First
50. A manufacturer makes the fans which force air through the boiler, the pollution control equipment, and out the stack; and delivers them to the powerplant site. The motors for the fans are manufactured and delivered. For a 1000 MWe plant, perhaps four fans of 7,000 HP each would be required.	18	38
51. A manufacturer makes the machines which will break the pieces of coal into a powder which can be easily moved into the boiler using air from the fans. The machinery is delivered to the powerplant site.	18	38
52. A manufacturer makes the equipment needed to control air pollution from the plant: this might include fabric filters to collect noncombustible ash, wet scrubbers to remove sulfur dioxide, or some other technologies.	24	38
53. A manufacturer makes the boiler (the boiler will weigh something like 2,000 tons). It is delivered to the power plant site in small pieces.	24	38
54. A manufacturer builds and delivers the generator, transformers, and switchgear.	30	38
55. A manufacturer builds the high, intermediate and low pressure steam turbines. (The low pressure turbine weighs around 300 tons). The turbines are delivered to the powerplant site.	30	38
56. A steel company makes the structural steel (columns and girders) that will be used to hold the boiler and steam turbines in place, and delivers it to the powerplant site.	16	38
57. The contractor places the concrete foundations for the powerplant and locates anchor bolts.	6	49
58. The contractor completes erection of the structural steel.	6	56 and 57

	Months	Tasks We Have to Finish First
59. The contractor finishes placing the major equipment components. These include the boiler shell, the air pollution control equipment, the fans that drive air into the boiler and through the air pollution control equipment, various electric motors, pumps, and the condenser.	18	50, 51, 52, 53 and 58
60. The contractor places the turbine/generator set in position and the transformers and switchgear are installed.	12	54 and 55
61. The contractor mounts cable trays on the structural steel to hold the electrical and control cables and wiring.	6	59 and 60
62. The construction crew installs the smaller electric motors and their control centers.	6	50 and 60
63. The heavy wire cables that will carry the electricity are installed. So is the wiring for the electrical controls for the powerplant.	3	61, 62, 74
64. In the powerplant there are many measuring instruments and controls. Each of these is checked against standards and adjusted if necessary.	6	63 and 66
65. The contractor installs the major piping to carry water and steam. The circulating water lines are about 12 feet in diameter and the high pressure steam piping is typically about 2 feet in diameter, with a 2-inch thick steel wall.	6	55 and 59
66. When the large diameter pipe has been hung on the structural steel, then the small pipe (less than 2-inches diameter) and the pressure lines for instrumentation are installed and connected.	6	65
67. The facilities to handle the solid wastes produced by the plant are constructed. This would include a flyash storage silo capable of holding 500 tons of flyash.	12	49
68. The contractor erects the ducts which will supply air to the boiler, and builds the flue gas passages to take the waste gases to the chimney.	9	59

	Months	Tasks We Have to Finish First
69. The contractor completes the erection of the chimney. The chimney is probably 500 to 800 feet tall, and contains several thousand tons of concrete. As soon as the ductwork is completed, work starts to hook up the chimney.	12	59 and 68
70. The contractor insulates the boiler and the ductwork. Aluminum sheet metal, called lagging, is placed over the insulation to prevent heat losses.	3	68
71. The operating crew begins start-up operations: they turn on each motor, wash the steam lines with acid and blow them clean, pressure test all air and water lines, and start the auxiliary boiler. All the controls and relays have to be adjusted during tests carried out over several months.	1	42 64, 67, 69 70, 74, 75
72. The utility signs contracts for the construction of facilities which will be needed on sites other than the power plant site. (Housing, maintenance shops, warehouses, auxiliary fuel storage, etc.)	12	35
73. The contractor completes construction of all the offsite facilities.	30	72
74. At the power plant site, the contractor completes the administration building, maintenance shops, and the control room with its instrument panels.	9	59
75. The emergency water supply reservoirs are filled.	12	44

One Year's Direct Energy Consumption in My Home

You have been studying a flow diagram of all the energy used in the United States in one year. In this exercise you will make a flow diagram for the energy used in your household in one year.

We cannot show many of the energy inputs to your household on this diagram, because it would be too difficult to estimate exactly how large they were. For example, the energy it took to produce your food, your clothing, and all the other things you bought is not included. We will include only your **direct** use of energy. If we could include **all** the energy your household used, the bars would be much bigger.

You can do this activity at home. You do not have to show your diagram to anyone at school.

Your teacher will give you a special graph to use in making your flow diagram. On the bottom are scales that will convert your energy purchases from physical units, like gallons of gasoline, to Btu's. On the graph, all energy is measured in Btu's.

Your teacher will show you an example of a completed graph. Shading the flows in different pencil colors makes a good-looking diagram.

You can use the spaces below to enter your household direct energy purchases from the records you made earlier.

One Year's Energy Purchases

Gasoline ________ gallons

Fuel oil ________ gallons

Wood ________ cords

Electricity ________ kilowatt hours

Natural gas ________ therms

Diesel fuel ________ gallons

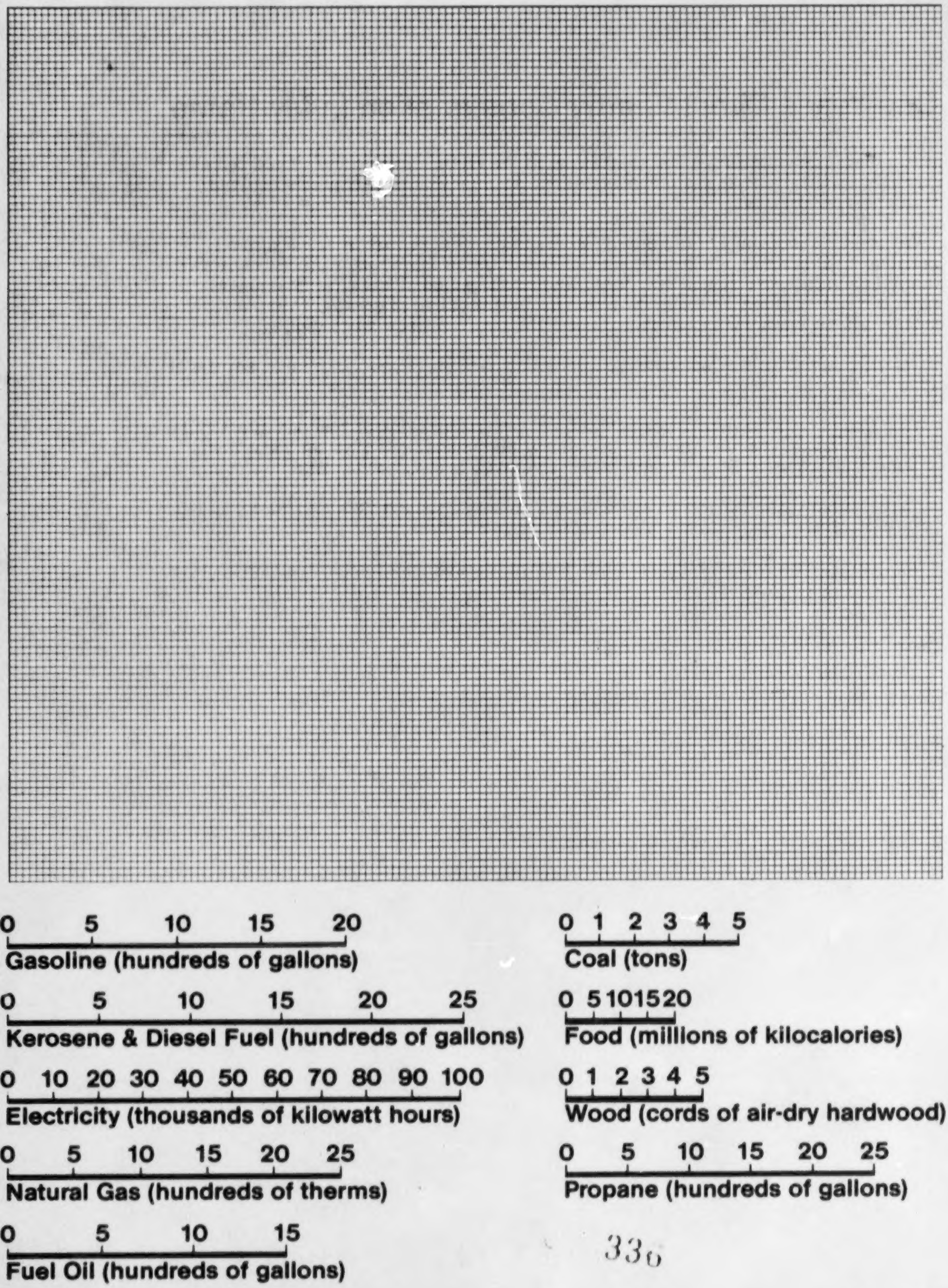
Propane ________ gallons

Coal ________ tons

Kerosene ________ gallons

Food ________ kilocalories

Vertical division = 5 million Btu



Unit Seven
Economics and Decisionmaking

Appliance Labelling

Objectives

This lesson contributes to the student's understanding of the following concepts:

Some appliances are more energy-efficient than others.

Energy-efficient appliances are often more expensive than less efficient models.

The law requires certain appliances be sold with labels which compare the energy consumption of that model with consumption by similar models.

To use the information on the label, the consumer also needs to know the purchase price of alternative models.

Format of the Lesson

Importance of well-informed shopping

Why some models use less energy:

water heater dishwasher

The appliance labelling law

Standard tests to get standard of comparison

Airconditioner label

Dishwasher label

Homework assignment

Materials Needed

overhead projector

screen

transparencies of different appliances

transparencies of labels

watercolor marker nonpermanent, for writing on transparencies

assignment sheet **Reading an Energy-Guide Label**, one per student

Importance of Well-informed Shopping

Ask students whether, when you're buying something, it makes any difference which one you buy? Try to direct attention to major appliances — "big purchases."

Tell the students it often happens that people will buy something and then later on realize they would have been better off had they bought a different model. Perhaps you can tell an anecdote about a time when this happened to you. Invite students to tell about any happenings like this they know about.

Ask students to list some ways in which a knowledgeable purchaser can save money. For example, a knowledgeable buyer might save money by selecting an appliance that:

used less energy

had lower repair bills

used less supplies to do its job (e.g., detergent in a clothes washer)

Tell the class that (surprise!) we'll consider the savings possible by reducing direct energy use.

Why Some Models Use Less Energy

Let's think about why two models that do basically the same job, may use very different amounts of energy. (Put on the water heater transparency.)

For example, here are two water heaters. They do the same job, but the one on the right uses less energy. Why? (ANS: more insulation reduces need for fuel. No pilot flame constantly using gas.)

Which do you think will cost more? Why? (ANS: one on right uses more materials, which will cost more. Probably was costlier to make, too.)?

Dishwashers

Let's look at dishwashers. Which one do you think will use less energy? (ANS: One on the left. Better insulation. More energy efficient motor. No heater during dry cycle.)

Which will cost more? (ANS: the one on the left.)

Help students see there may be good reasons why an energy-efficient appliance may cost more to manufacture than a less efficient model that does the same job. (Note that this is NOT always the case.) This difference will usually, though not always, be reflected in a higher purchase price.

Review that the purchaser can often get that money back and more through savings on the cost of the energy used by the appliance.

To know whether the more expensive appliance will save money in the long run, you need to be able to calculate what the cost of the energy used by different models will be. This can be a real headache.

What are some sources of information? Students may mention consumer publications, the nameplate of the appliance, or manufacturer's brochures.

The Appliance Labelling Law

To make it easier for consumers to know whether it would pay them to buy a more energy efficient model, Congress passed a law requiring manufacturers to put labels on the types of appliances that use the most energy and have the greatest model-to-model variation in energy consumption.

These labels compare the amount of energy the labelled appliance uses with the amount used by similar appliances.

Starting in December 1980, the following kinds of appliances must have an energy label:

refrigerators

freezers

refrigerator-freezers

dishwashers

clothes washers

room air conditioners

furnaces (but the label isn't much help)

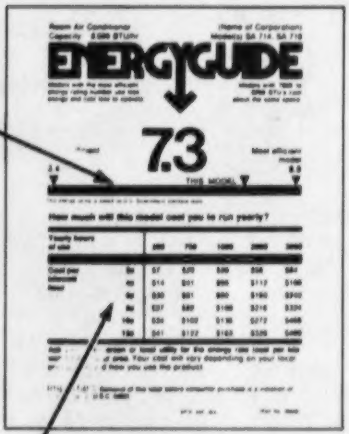
Where Do the Figures Come From: A Common Standard

So that consumers would be able to compare models, the government had standard tests designed that would estimate how much energy a particular appliance would use in a year.

Ask students to describe the EPA mileage ratings for cars. The EPA tests cars to estimate how many miles per gallon they'll get. It is unlikely you'll get the same mileage, but at least all the cars took the same test. This provides a common basis for comparison. The same is true of the appliance tests.

Examining the Label

Put on the overhead transparency of the room air conditioner label.


ENERGYGUIDE
7.3
THIS MODEL
How much will this model cost you to run yearly?

"Here's a label for a room air conditioner. Notice in the middle there's a bar. The left end of the bar represents the least energy efficient air conditioner this size that anybody sells. It got an EER rating of 3.4. EER stands for Energy Efficiency Rating. This is a measure the government developed to describe the efficiency of air conditioners. The other end of the bar represents the most efficient model. It got an 8.5. The model this label's one got a 7.3. You can see right away from the bar that a 7.3 rating is pretty high up on the scale.

"But does that ell us this is the model to buy? Not necessarily, because we don't know whether we'd save.

"Down below is a table to help us figure out how much the electricity for this air conditioner will cost. Let's see how we can use it."

(In doing the following calculation, use figures that would be reasonable for your climate. Make a table on the chalkboard.)

"Would you use an air conditioner in January?" (ANS: no) "February?" (ANS: no) "March?" (ANS: no) "April?" (ANS: no) "May "May?" (ANS: maybe a little bit) "How many days? How many hours each day? (ANS: 2 or 3 days, 2 hours a day). On the chalkboard, write May = 6 hours.

"June?" (ANS: Everyday, from 11 a.m. to 4:00 p.m.) 5 hours x 31 days = 155 hours)

"July?" (ANS: Everyday, from 7 a.m. to 6:00 p.m.) 11 hours x 31 days = 341 hours)

And so forth through the remainder of the year, creating a guesstimate of annual hours of operation. In our hypothetical example, we'll say the grand total is 1354 hours, and that electricity costs 6¢ kWh. We can get close to 1354 by combining amounts from the chart.

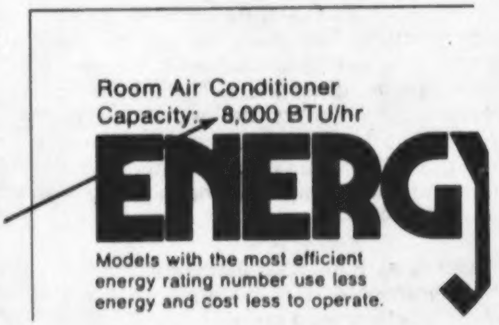
1000 = $108

250 hours = $ 27

1250 hours = $135

"So the electricity will cost more than $135 per year. Does this tell us this is the one to buy? No, it doesn't. We need to know what our money will buy in similar models.

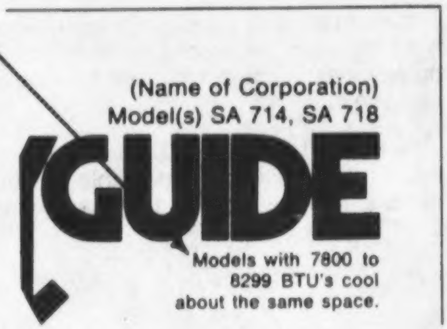
"What will be a similar model? The label tells us. It says this air conditioner has a capacity of 8000 Btu per hour. That's how many Btu it can remove from the room each hour. And down here it tells us that air conditioners from 7800 to 8299 Btu per hour are lumped together.



Room Air Conditioner
Capacity: 8,000 BTU/hr

ENERGY

Models with the most efficient energy rating number use less energy and cost less to operate.



(Name of Corporation)
Model(s) SA 714, SA 718

GUIDE

Models with 7800 to 8299 BTU's cool about the same space.

Dishwasher Label

"Let's look at another label, one for a standard capacity dishwasher.

"Notice this time we have two bars — one to use if you heat water electrically, and one if you heat water with natural gas. Last time the most energy efficient model was at the right end of the bar. Where is the most energy efficient model this time?" (ANS: on the left, because that's the model with the lowest energy cost.)

"How would you rate the energy efficiency of this model?" (ANS: Pretty good, not the best but better than half-way between most and least costly.)

"Notice up here it tells you how they arrived at the $60 figure. It says estimates on the scale are based on a national average electricity rate of 4.97¢ per kilowatt-hour and a natural gas rate of 36.7¢ per therm.

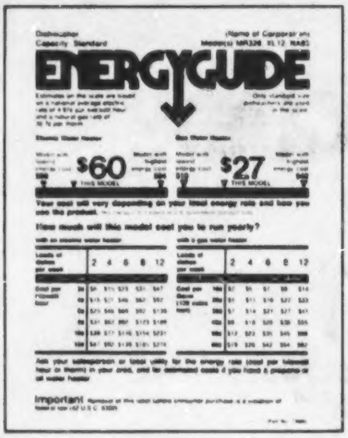
"If the $60 is based on a cost of electricity of 4.97¢ per kilowatt-hour, how many loads of dishes do they expect the dishwasher to do in a week?" (ANS: about 7).

Homework

Pass out the assignment sheet.

The answers to worksheet are as follows:

1. $91
2. $68
3. $132
4. $132-91 = $41
5. 4.97¢ per kilowatt-hour
6. $266
7. $182
8. 5 and a half years ($800-$700) – ($74-$55)
9. 2.7 years. ($800-$700) – ($146-$109)
10. 22.5 – 24.4 cubic feet
11. automatic defrost



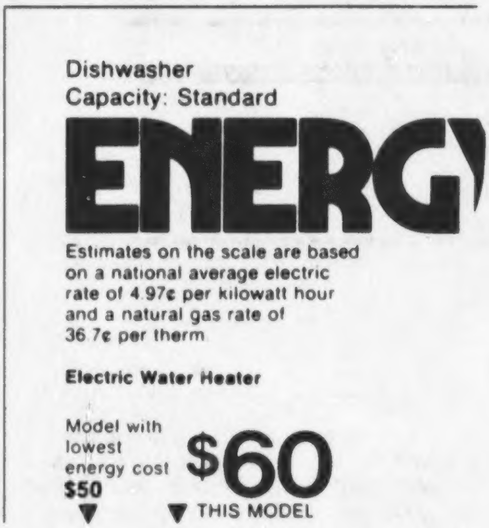
ENERGYGUIDE

$60
THIS MODEL

$27
THIS MODEL

How much will this model cost you to run yearly?

Important



Dishwasher
Capacity: Standard

ENERG

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour and a natural gas rate of 36.7¢ per therm.

Electric Water Heater

Model with lowest energy cost
$50

$60
THIS MODEL

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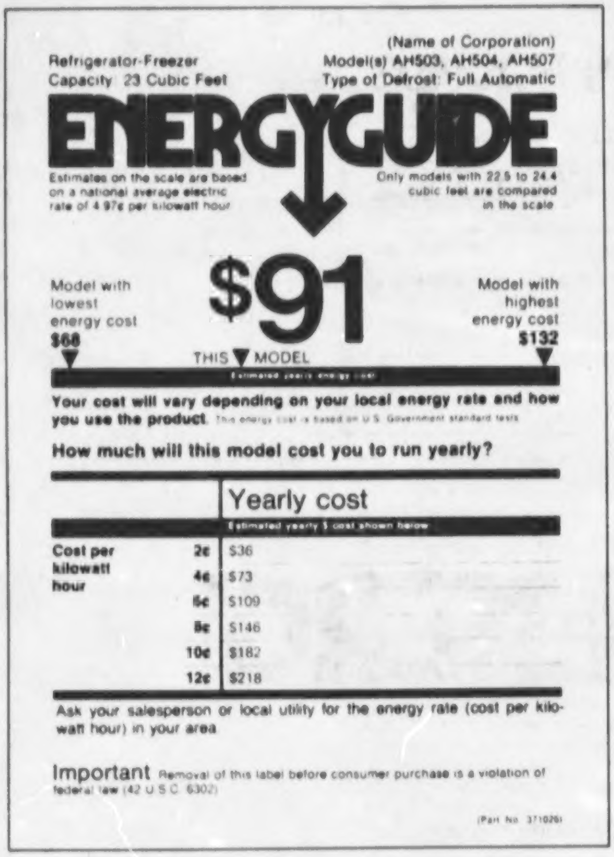
Reading an Energy Guide Label



(Name of Corporation)
Refrigerator-Freezer
Capacity: 23 Cubic Feet
Model(s) AH503, AH504, AH507
Type of Defrost: Full Automatic

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour

Only models with 22.5 to 24.4 cubic feet are compared in the scale

$91

Model with lowest energy cost **$68**

THIS MODEL

Model with highest energy cost **$132**

Estimated yearly energy cost

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests.

How much will this model cost you to run yearly?

		Yearly cost Estimated yearly $ cost shown below
Cost per kilowatt hour	**2¢**	$36
	4¢	$73
	6¢	$109
	8¢	$146
	10¢	$182
	12¢	$218

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

Important Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

(Part No. 371026)

Here is an example of a kind of label that will be put on all new refrigerators, freezers, refrigerator/freezers, water heaters, dishwashers, furnaces, clothes washers, and air conditioners.

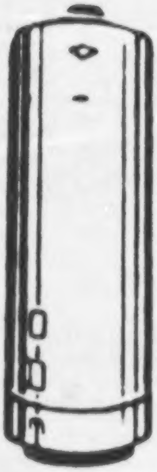
The label above is for a refrigerator. Study it, then answer the questions below on a separate sheet of paper. Your parents may help you.

1. What is the estimated yearly energy cost of this model?
2. What is the estimated yearly energy cost of the model with the lowest energy cost?
3. What is the estimated yearly energy cost of the model with the highest energy cost?
4. How much could you expect to save each year if you had this model instead of the least efficient one?
5. The estimated yearly energy cost is based on a national average electric rate of how much?
6.* (optional) If the national average electric rate were 10¢ per kilowatt-hour instead of 4.97¢, what would the estimated yearly energy cost of the model with the highest energy cost be?
7. How much would it cost to run this refrigerator for a year if electricity in your area cost 10¢ per kilowatt-hour?

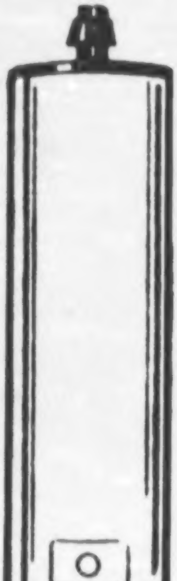
Here is the yearly cost table from the label on the model that has an estimated yearly energy cost of $68. Use it in answering the next two questions:

		Yearly Cost
Cost per	2¢	$27
kilowatt	4¢	$55
hour	6¢	$82
	8¢	$109
	10¢	$137
	12¢	$164

8. Suppose the purchase price of the model with the $91 annual energy cost was $700, and the purchase price of the model with the $68 energy cost was $800. At an electric rate of 4¢ a kilowatt-hour, how long would it take to recover the added appliance cost from utility bill savings? (Ignore the cost of using the money this way.)
9. At an electric rate of 8¢ a kilowatt-hour, how many years would it take?
10. In comparison shopping for energy savings we need to compare models that do the same job. What range of refrigerator sizes are being compared on this label?
11. We might decide this is the size we need but don't need all features. Some features use a lot of energy. Look in the upper right hand part of this label. What feature might we do without that would put us into a whole different group of models, with lower energy costs.



two inch insulation



four inch insulation

automatic flue damper closes when burner is not firing, prevents air from rising through flue and cooling water in storage.

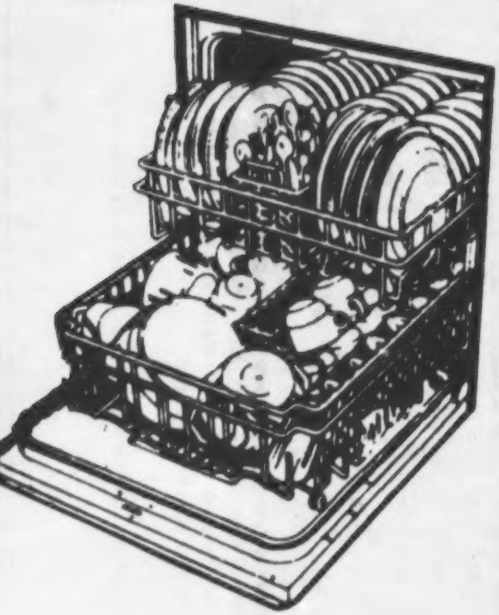
pilotless electric ignition of flame

copper fin flue baffle maximizes transmission of heat from flue gases to water

special dip tube

air injection burner ensures complete combustion

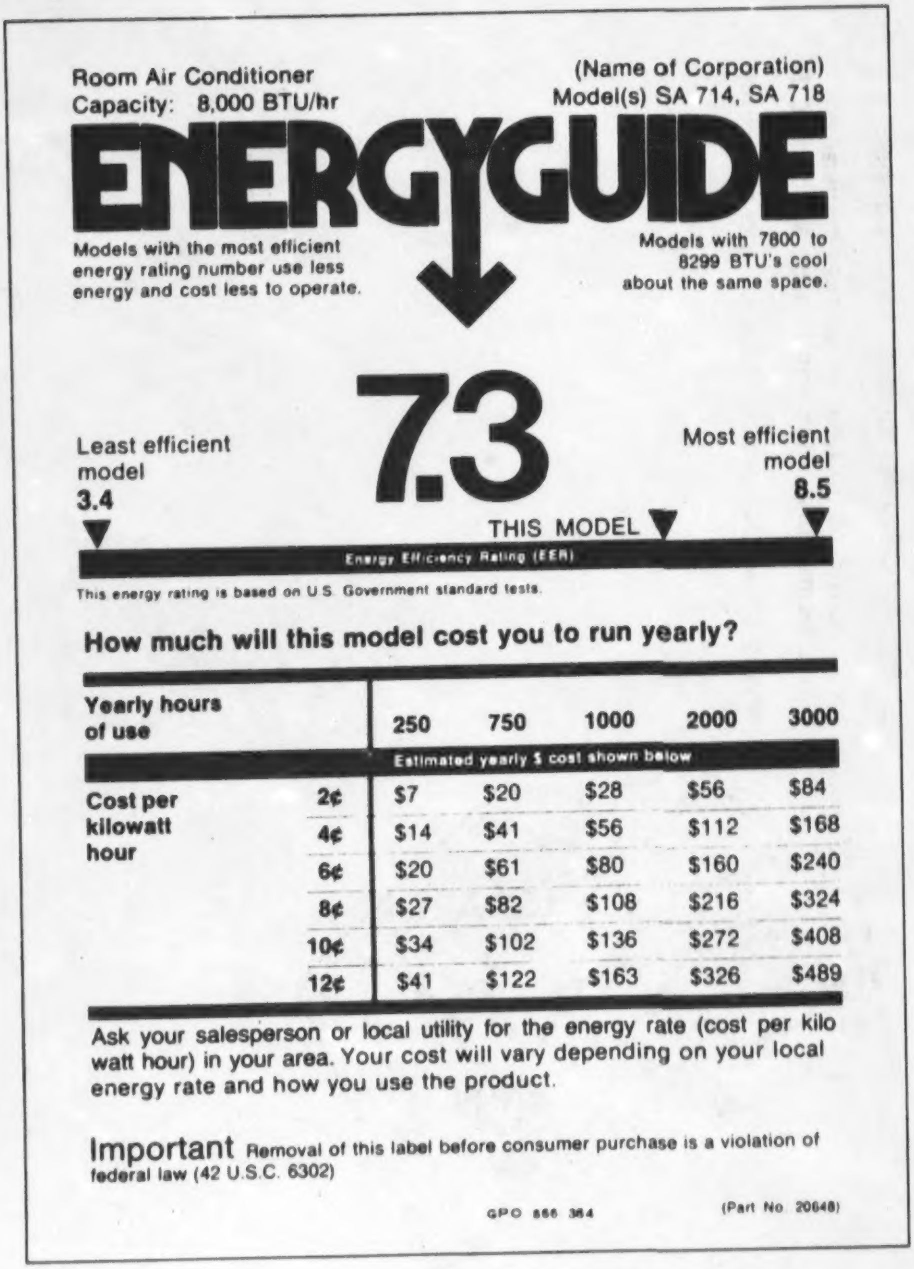
Features shown represent an idealized heater and not necessarily one which is cost-effective or commercially available.



energy-efficient motor uses more copper

has internal water heater, so that household water heater does not need to be set at 140°F

drying cycle uses circulating air, no extra heating



Room Air Conditioner
Capacity: 8,000 BTU/hr

(Name of Corporation)
Model(s) SA 714, SA 718

ENERGYGUIDE

Models with the most efficient energy rating number use less energy and cost less to operate.

Models with 7800 to 8299 BTU's cool about the same space.

7.3

Least efficient model
3.4

THIS MODEL

Most efficient model
8.5

Energy Efficiency Rating (EER)

This energy rating is based on U.S. Government standard tests.

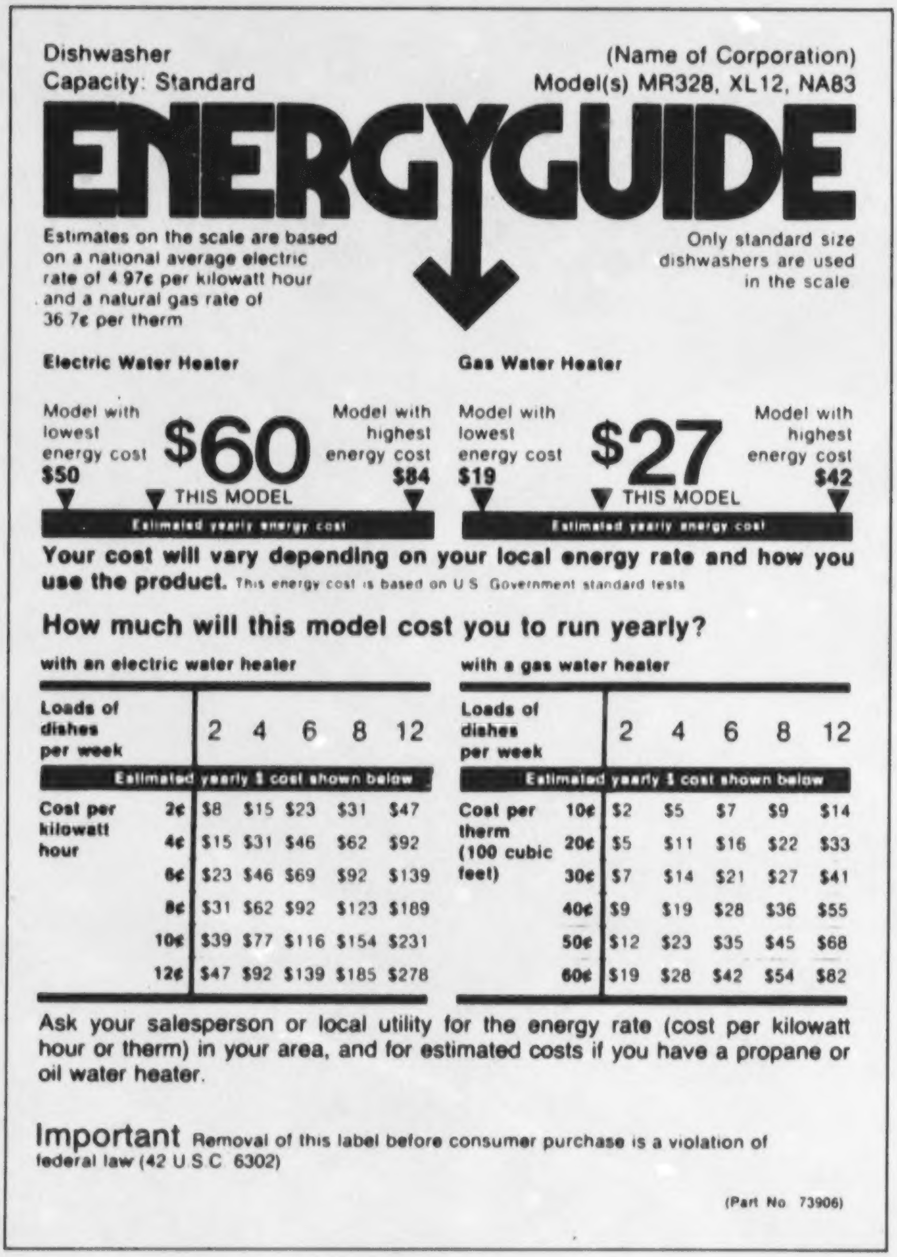
How much will this model cost you to run yearly?

Yearly hours of use		**250**	**750**	**1000**	**2000**	**3000**
		Estimated yearly $ cost shown below				
Cost per kilowatt hour	**2¢**	$7	$20	$28	$56	$84
	4¢	$14	$41	$56	$112	$168
	6¢	$20	$61	$80	$160	$240
	8¢	$27	$82	$108	$216	$324
	10¢	$34	$102	$136	$272	$408
	12¢	$41	$122	$163	$326	$489

Ask your salesperson or local utility for the energy rate (cost per kilo watt hour) in your area. Your cost will vary depending on your local energy rate and how you use the product.

Important Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

GPO 866 364 (Part No. 20648)



Dishwasher
Capacity: Standard

(Name of Corporation)
Model(s) MR328, XL12, NA83

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour and a natural gas rate of 36.7¢ per therm

Only standard size dishwashers are used in the scale

Electric Water Heater

Model with lowest energy cost **$50**

$60
THIS MODEL

Model with highest energy cost **$84**

Estimated yearly energy cost

Gas Water Heater

Model with lowest energy cost **$19**

$27
THIS MODEL

Model with highest energy cost **$42**

Estimated yearly energy cost

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests

How much will this model cost you to run yearly?

with an electric water heater

Loads of dishes per week		2	4	6	8	12
Estimated yearly $ cost shown below						
Cost per kilowatt hour	**2¢**	$8	$15	$23	$31	$47
	4¢	$15	$31	$46	$62	$92
	6¢	$23	$46	$69	$92	$139
	8¢	$31	$62	$92	$123	$189
	10¢	$39	$77	$116	$154	$231
	12¢	$47	$92	$139	$185	$278

with a gas water heater

Loads of dishes per week		2	4	6	8	12
Estimated yearly $ cost shown below						
Cost per therm (100 cubic feet)	**10¢**	$2	$5	$7	$9	$14
	20¢	$5	$11	$16	$22	$33
	30¢	$7	$14	$21	$27	$41
	40¢	$9	$19	$28	$36	$55
	50¢	$12	$23	$35	$45	$68
	60¢	$19	$28	$42	$54	$82

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour or therm) in your area, and for estimated costs if you have a propane or oil water heater.

Important Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

(Part No. 73906)

The Landlord-Tenant Dilemma

Objectives

This lesson contributes to students' understanding of the following concepts:

People tend to do things that make or save them money.

When energy costs are not paid by the user, there is less incentive to use energy efficiently.

It is sometimes very difficult to assign costs to the actual user.

Format of the Lesson

Discuss idea of incentives

Explain activity and put diagram on chalkboard

Do seven situations, with students' explanations and class discussion

Class comparison of landlord pays/ tenant pays

Materials Needed

chalkboard

class roster marked to indicate 14 pairs of landlord and tenant.

Setting Up the Activity

On the board, chalk a big diagram like the one below. Make each column large enough for a student to stand in front of it.

	Landlord Pays		Tenant Pays	
(situation)	Landlord	Tenant	Landlord	Tenant
1.				
2.				
3.				
4.				
5.				
6.				
7.				

Tell the class, "I'm now going to describe seven situations in which there's an opportunity to save energy. For each situation, I'll appoint two landlords and two tenants.

"Landlords and tenants, when they're called on, should come up and stand in front of one of the signs saying what they are. Notice that in one landlord-tenant pair, the landlord pays the utility bills, in the other the tenant does. Listen carefully while I describe the situation. Then, pretending you are the landlord or the tenant, explain to us whether you would take that step or not, and why. Write your decision on the board: yes or no.

"Sometimes you won't be the one who could do that thing. In that case write 'no control.'

"Then the class will discuss whether they think you did what a landlord or tenant would actually do under those circumstances. If they decide to do so, the class can change your decision.

"OK, let's begin."

Appoint two pairs of landlords and tenants.

Read the following description.

"One. This describes a furnished apartment. The refrigerator comes with the apartment. Now, the old refrigerator is worn out and the landlord has to buy a new one. The landlord can get a good refrigerator for $700. But by paying a hundred dollars more, the landlord can get a more energy-efficient model that will save about $500 in electrical bills during its lifetime. Will the landlord buy the more expensive model that uses less electricity?"

Give the students a moment to think, then call on the landlords and tenants one by one from left to right. Notice that the tenants cannot make this decision. They should write "no control" when called upon.

Ask the class whether they think the "landlords" made the decision a landlord really would. (The landlord paying the electric bills would be smart to buy the energy-efficient refrigerator; the other would get no money return for the extra hundred dollars.)

Appoint two new landlord-tenant pairs.

"Two. This is an unfurnished apartment. The tenant provides all the furniture, even the stove and refrigerator. The refrigerator has just worn out, and the tenant needs to buy a new one. (The tenant is planning on staying in this apartment for a long time.) The tenant can get a good refrigerator for $700. But by paying $100 more, the tenant can get a more energy-efficient model that would save about $500 in electrical bills during its lifetime. Will the tenant buy the more expensive model that uses less electricity?"

Conduct discussion as before. This time, the landlords will have to write "no control." The tenant who is paying the utility bills has reason to spend the extra money for the refrigerator that uses less elelctricity; the other tenant doesn't.

"Three. The apartment has a dishwasher. The tenant is in the habit of running it after every meal, even though it may only have a couple of dishes in it. A visitor points out that, if the tenant ran the dishwasher only once a day several dollars worth of electricity could be saved each month and the dishes would be just as clean. The tenant is surprised to see how much energy could be saved and sees it's probably true, although he/she doesn't like having dirty dishes sitting around and, besides, putting away a whole load of dishes at once is a drag.

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Will the tenant decide to run the dishwasher only once a day?"

The responses and discussion should reveal that the tenant who is not paying for the electricity has little incentive to conserve. Ask the class to think about who is actually paying for this electricity in the case of the non-conserving, non-paying tenant.

In fact, the landlord probably sets her rents by including a standard, per-apartment charge for utilities. She probably figures how much this should be by dividing her utility bills by the number of apartments. In other words, tenants who use less than the average amount of energy will be paying for the "extra" electricity used by tenants who use more than the average amount of electricity.

Of course, the landlord can only raise her rents so far before people will choose other apartments. She is competing with other landlords.

What incentive does this give her to encourage energy conservation among her tenants?

"Four. This tenant has a lifelong habit of not turning off lights. The cost of electricity has doubled and the tenant is trying to save some money.

Will the tenant make a resolution to turn off lights on leaving the room?"

"Five. This apartment was built a long time ago and has no insulation at all. A reputable contractor has done an energy audit of the building. Her figures show that insulating the attic would greatly decrease the amount of energy needed to heat the apartment. The fuel saving alone would pay for the insulation in two years. Still, the cost of insulation and installation would amount to over a thousand dollars.

Will you order the insulation?"

Note that the tenant paying utility bills might reasonably decide to pay for the insulation, since he could save money if he remained long enough.

"Six. We are buying light bulbs for the hallways of the apartment house. (Sometimes the tenants buy them when they're burned out because they feel a well-lit hall discourages criminals, and they don't want to wait the days it often takes the custodian to come from the landlord's other buildings.) The lights by each apartment are connected to the electrical system of that apartment.

You can choose one of two different kinds of bulbs. They cost about the same and use the same number of watts. One type of bulb is your average light bulb. The other kind lasts much longer, so bulb changes are less frequent, but it gives less light.

Will you buy the kind that gives the most light per watt?"

This is a more complicated situation, because it presents conflicts for the individual.

The landlord may not care at all about the light levels in the hall; or he may care because if the building has a reputation for being crime-infested it will reduce what he can charge for rent (less demand) and lower its selling price. He may care a lot about the expense of changing bulbs, since he is paying the custodian who could be doing other things. Ask the landlords whether it costs them anything to change the bulb. Don't let it be assumed that purchase price and utility bills are the only cost to the landlord of choosing this bulb.

The tenants are there anyway and so probably don't consider bulb changing an expense.

"Seven. It is time to install a new water-heater and furnace in the apartment. Together, these appliances use over half of all the energy used in the apartment. The landlord has to buy them, and it's the old story — for more money, you can buy models that use less energy.

Will you buy the energy efficient models?"

Concluding Discussion

Review what has been put on the board. It should look something like this:

	Landlord Pays Bills		Tenant Pays Bills	
	Landlord	Tenant	Landlord	Tenant
1. landlord buys fridge	yes	n/c *	no	n/c
2. tenant buys fridge	n/c	no	n/c	yes
3. dishwasher habits	n/c	no	n/c	yes
4. turn off lights	n/c	no	n/c	yes
5. insulation	yes	no	no?	yes/no
6. light bulbs	yes/no	yes	yes/no	yes
7. furnace/water heater	yes	n/c	no	n/c

* n/c = no control

Discuss the following questions:

In which of the situations did one person stick another with higher utility bills, and the second person couldn't do anything about it?

Which leads to greater energy consumption, the tenant paying or landlord paying? Is either choice clearly better?

When the landlord pays, certain kinds of conservation are encouraged. What are they? (ANS: Big capital investments for insulation, new furnaces, etc.)

When the tenant pays, certain kinds or ways of conserving are encouraged. Can you describe them? (ANS: Thrifty habits.)

Can you think of any way in this situation where we can have our cake and eat it too? How?

Implications

What kinds of energy savings are possible in a school?

What incentives are possible for school districts?

What can only be done by the school board? . . . by custodians? . . . by teachers? . . . by students? What kind of incentives could you provide for each group?

10 10 TEN E80 10 10	5 5 FIVE E80 5 5	1 1 ONE E80 1 1
10 10 TEN E80 10 10	5 5 FIVE E80 5 5	1 1 ONE E80 1 1
20 20 TWENTY E80 20 20	5 5 FIVE E80 5 5	1 1 ONE E80 1 1
20 20 TWENTY E80 20 20	50 50 FIFTY E80 50 50	1 1 ONE E80 1 1

500 500 FIVE HUNDRED E80 500 500	100 100 ONE HUNDRED E80 100 100	100 100 ONE HUNDRED E80 100 100
500 500 FIVE HUNDRED E80 500 500	1,000 1,000 ONE THOUSAND E80 1,000 1,000	100 100 ONE HUNDRED E80 100 100
500 500 FIVE HUNDRED E80 500 500	1,000 1,000 ONE THOUSAND E80 1,000 1,000	100 100 ONE HUNDRED E80 100 100
500 500 FIVE HUNDRED E80 500 500	10,000 10,000 TEN THOUSAND E80 10,000 10,000	100 100 ONE HUNDRED E80 100 100

Unit Eight
Conservation

Fairness

The great novelist Leo Tolstoy expressed the feelings of many people when he wrote that it is "a shame to use for one's own pleasure what another person needs to live."

1. Do you agree with Tolstoy? Why or why not?

2. Think of an example of using energy for pleasure. Think of another example in which the same energy source is used to provide something someone needs to live.

3. Does the "pleasure" use really lessen the amount of energy available for the "necessity" use? If you think so, describe exactly how the two would be connected.

4. Suppose there is a shortage of diesel fuel. Farmers will be unable to plant all their cornland. The government could allocate the available fuel to farmers (taking it away from, say, truck drivers). Do you think that is the right thing to do?

5. Suppose most of the corn raised will be exported. Would that change your opinion?

6. Suppose must of the grain will be fed to pigs and cows. Would that change your opinion?

7. Some people have suggested that, because the United States is a wealthy nation, it should concentrate on developing energy sources that require a lot of expertise and capital to get started, such as solar and nuclear energy. That would leave the petroleum, which can be used in cheap equipment and with relatively little knowledge, to the world's underdeveloped nations.

What do you think of this idea? Discuss it in terms of economics and then in terms of ethics.

This Is the Big Payoff!

In this project, you will try to figure out the **best** way for your family to lower their energy bills. Pretend you have some money to spend on home insulation, a new car, a flow constrictor for the shower, or anything else. You will make five separate reports, pretending you have $10, $100, $500, $2,000, or $10,000 to spend. In each of the five reports, tell:

1. What you would do. You can do more than one thing, as long as the total costs don't exceed the available dollars.

2. How much it would cost. Try to include names of suppliers who would really sell you the material and what their prices are. You may include ads if you want.

3. How it works.

4. How much energy you would expect to save. Include all your calculations. For example, if you are going to put storm windows on your house, we would want to know how many square feet of windows you had, how many Btu's you estimated were lost through those windows in a winter, and how much you expected supplying those Btu's would have cost each year for the life of the storm windows.

5. What the payback period would be.

These reports will not be due for many weeks. This will give you a chance to think about them while we are studying different ways people can conserve energy.

You may get all the help you want from anyone you wish in thinking about this project, but you must write the reports all by yourself.

Your reports will be graded on:

1. How much money you can save for every dollar you invest.

2. How convincing your calculation of savings is.

3. The ingenuity you show in finding the best solution for your particular family.

4. How complete and accurate the figures backing up your estimates are.

5. How well you have researched what's available.

6. The clarity and neatness of your presentation.

Good luck!

Out the Windows!

In this exercise, we will estimate how much heat your home loses by conduction through its windows during a typical heating season, and how much that heat costs. First, we need to know the number of degree-days of heating in your locality. It is ______________________________ degree-days.

Different kinds of windows lose heat at different rates. Below are some R-values typical of different kinds of windows. If you're not sure of the size of the air space, guess.

Go around your home with a ruler and measure the size of the glass in each window. (144 square inches = one square foot). Your teacher may be able to give you some forms to help you do this. Add up the square footage of all the windows of each type and enter them in the table below. Divide by the R-value. Total the results. You now know how many Btu would be lost in one hour through all your windows if there was one degree Fahrenheit difference between inside and outside. To find heat loss for the year, multiply by 24 (hours in a day, to get loss in a day) and by the number of degree-days.

Total square footage of all windows of this type

R-value (reciprocal of Btu per hour per square foot per degrees Fahrenheit difference between inside and outside

Window Type					
Single glass	______ sq. feet	÷	0.88	=	______
Double glass, 3/16" air space	______ sq. feet	÷	1.49	=	______
Double glass, 1/4" air space	______ sq. feet	÷	1.64	=	______
Double glass, 1/2" air space	______ sq. feet	÷	1.73	=	______
Double glass, 3/4" air space	______ sq. feet	÷	1.82	=	______
Single glass with storm window	______ sq. feet	÷	1.89	=	______
Double glass with storm window	______ sq. feet	÷	2.65	=	______
			TOTAL		______

______________ degree-days x 24 hours in a day x ______________ = ______________ Btu's lost

This is the total number of Btu's lost by conduction in one heating season.

Insulation Where We Don't Want It

Insulation slows down the flow of heat. In the cold winter, insulation keeps heat inside the house from flowing to the outside. In the summer, it slows down the flow of outside heat into the house.

But sometimes we want heat to flow as fast as possible! We don't want to insulate. Check for these kinds of unwanted insulation in your home.

1. Every refrigerator has a coil. Usually it is in the back. Sometimes it is underneath. A fluid flowing through the coil carries heat from inside the refrigerator to the outside. So we want heat to escape from the coil as fast as possible.

The coil is usually painted black. Why?

Coils get dusty. The dust is an insulator that slows down the circulation of air around the coil. That makes the refrigerator less efficient.

If your refrigerator's coil is dusty, dust it off. A paint brush is excellent; a vacuum attachment works too. Be careful not to bend or damage the coil.

2. Is your home heated with radiators? Steam or hot water circulates through a radiator. The heat travels from the radiator to the things in the room by conduction and radiation. Some electrically heated homes use baseboard radiators.

Is your radiator insulated by dust? Fix it up.

3. Every air conditioner has a coil. Like the coil on a refrigerator, the air conditioner's coil exhausts heat taken from inside into the outside air. We want this heat to flow as fast as possible.

With the help of a family member, check the coil of your air conditioner or heat pump. Is it free of dust?

While you're at it, check to see whether direct sunlight can strike the coil. Why is this bad? What could you do about it?

Instructions to the Computer

Imagine that there is a computer in your house. This computer is connected to every electrical switch in the house, so that it can turn any light or appliance on or off. It is also connected to the furnace and air conditioner. It has a built-in clock that tells it what time, day of the week, and date it is, and it has a gadget in each room that tells it whether there is anybody in the room. (But it can't tell the difference between a dog and a person). It can tell the temperature outside and the temperature in each room inside.

You want to use this computer to save energy in your house. What instructions will you give it? (You can also add extra ways of getting information to the computer if you want.)

To help you get started, here are half of two sample instructions. You can complete and use them.

1. If nobody is in the room, then ____

____.

2. If it is between 9 p.m. and 6 a.m. and there's nobody in any room except the

bedrooms, then ____.

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